UNCLASSIFIED

AD NUMBER
ADB010592
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies only; Test and Evaluation; JAN 1976. Other requests shall be referred to Air Force Flight Dynamics Laboratory, FBR, Wright-Patterson AFB, OH 45433.**
AUTHORITY
afal ltr, 22 may 1978

THIS PAGE IS UNCLASSIFIED

THIS REPORT HAS BEEN DELIMITED
AND CLEARED FOR PUBLIC RELEASE
UNDER DOD DIRECTIVE 5200.20 AND
NO RESTRICTIONS ARE IMPOSED UPON
ITS USE AND DISCLOSURE.

DISTRIBUTION STATEMENT A

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED.

150
2-75

(2)

AFFDL-TR-76-1

ADB010592

COMPUTER PROGRAM (NOLAST) FOR NON-LINEAR ANALYSIS OF COMPOSITE LAMINATES

TECHNICAL REPORT AFFDL-TR-76-1

FEBRUARY 1976

AD No.____
DDC FILE COPY

Distribution limited to U.S. Government agencies and other designated recipients only; test and evaluation; statement applied January 1976. Other requests for this document must be referred to Air Force Flight Dynamics Laboratory (FBR), Wright-Patterson Air Force Base, Ohio 45433.

DDC
RECEIVED
APR 30 1976
B

AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio 45433

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

The distribution of this report is limited to U.S. Government agencies and other designated recepients only. Other requests for this document must be referred to Air Force Flight Dynamics Laboratory (FBR), Wright-Patterson AFB, Ohio 45433.

This technical report has been reviewed and is approved for publication.

LASZLO BERKE, Acting Chief
Design and Analysis Branch
Structures Division
AF Flight Dynamics Laboratory

ACCESSION for
NTIS
DDC
UNANNOUNCED
JUSTIFICATION
BY
DISTRIBUTION/AVAILABILITY CODES
Dist.
B

FOR THE COMMANDER:

GERALD G. LEIGH, Lt Col, USAF
Chief, Structures Division
AF Flight Dynamics Laboratory

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

AIR FORCE - 7 APRIL 1976 — 150

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

14

1. REPORT NUMBER: AFFDL-TR-76-1

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

9 Technical rept.

6

4. TITLE (and Subtitle): COMPUTER PROGRAM (NOLAST) FOR NON-LINEAR ANALYSIS OF COMPOSITE LAMINATES.

5. TYPE OF REPORT & PERIOD COVERED

6. PERFORMING ORG. REPORT NUMBER

10

7. AUTHOR(s): R. S. Sandhu

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Air Force Flight Dynamics Laboratory
Air Force Wright Aeronautical Laboratories
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio 45433

16

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
AF-1467
17 146702
~~14670246~~

11. CONTROLLING OFFICE NAME AND ADDRESS
Design and Analysis Branch (AFFDL/FBR)
Structures Division
Air Force Flight Dynamics Laboratory

11

12. REPORT DATE: Feb[redacted]76

13. NUMBER OF PAGES: 67

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

12 74p.

15. SECURITY CLASS. (of this report): Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Distribution limited to U.S. Government and other designated recipients only; test and evaluation; statement applied January 1976. Other requests for this document must be referred to Air Force Flight-Dynamics Laboratory (FBR), Wright-Patterson AFB, Ohio 45433.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Laminate Strength, Laminated Composites, Failure Criterion, Numerical Analysis, Nonlinear Analysis, Inelasticity Stress Analysis.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The computer program NOLAST predicts the response of multidirectional laminates subjected to in-plane loads. It uses piecewise cubic spline interpolation functions to represent the basic stress-strain data. This yields smooth composite strain-strain curves from which accurate moduli of elasticity over the entire range can be determined. Loads are applied incrementally. The predictor corrector and iterative method employed renders the present approach practically independent of the size of load increment. The ultimate cumulative

(Continued on Back)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Next page

1

012 070

response of the laminate is determined by ply-wise application of an energy based failure criterion.

FOREWORD

This work was performed by R. S. Sandhu of the Design and Analysis Branch, Structures Division, Air Force Flight Dynamics Laboratory under Project 1467, "Structural Analysis Methods," Task No. 146702, "Structural Analysis Methods for Aerospace Vehicles," and Work Unit 14670246, "Automated Design of Advanced Aerospace Structures".

The manuscript was released in November 1975.

TABLE OF CONTENTS

PRECEDING PAGE BLANK-NOT FILMED

LIST OF ILLUSTRATIONS

SECTION I

INTRODUCTION

Composite laminates are increasingly being used in the design of structural components of flight vehicles. To evolve an efficient design of components, it is necessary to know behavior of the laminates under various combinations of loads. This behavior can be determined experimentally but this is both expensive and inconvenient. The alternative to the purely experimental technique is to determine the analytical response of laminates based upon the mechanical properties of unidirectional laminas and to conduct some limited experimental verification. Analytical technique relating the properties of the unidirectional laminas to those of the laminates is documented in References 1 and 2.

The concepts developed in References 1 and 2 form the basis of a NOnlinear LAminate STrength (NOLAST) analysis computer program which is the subject of this report. The NOLAST program predicts the rsponse of multidirectional laminates subjected to in-plane loads.

A general description of the program is included in Section II while Sections III and IV contain user's instructions and program modifications along with sample problems. The Fortran listing of the program and examples of output appear in Appendices A and B respectively.

SECTION II

PROGRAM DESCRIPTION

The program NOLAST is designed to analyze multidirectional laminates subjected to monotonically increasing proportional in-plane loads to failure. In the prediction process, it uses the following:

1. The incremental constitutive relationship for a unidirectional lamina

$$d\epsilon_i = S_{ij}\ (\epsilon_i)\ d\ \sigma_j \quad (i,\ j = 1,\ 2,\ 6) \tag{1}$$

where $d\epsilon_i$, $d\sigma_j$, S_{ij} (ϵ_i) are stress and strain components and elements of the compliance matrix. For accurate determination of S_{ij} etc., experimentally obtained basic stress-strain data (uniaxial tension and compression along and transverse to the material axes and longitudinal shear) of the unidirectional lamina are represented by piecewise cubic spline interpolation functions to yield smooth composite stress-strain curves. The spacing of the stress-strain points of the experimental data can be chosen arbitrarily.

2. In paragraph 1, elements of the compliance matrix, S_{ij} (ϵ_i), are functions of strains (ϵ_i) resulting from simple load conditions. In case the stress-strain curves of the lamina are highly nonlinear, the use of strain components under biaxial stresses would have significant effect on the predicted behavior of the laminate. The presence of a compressive stress in the transverse dir tion in combination with a tensile stress in the longitudinal direction is likely to result in the reduction of the

apparent longitudinal tensile tangenet modulus. The reverse situation would occur if the transverse stress were tensile. The quantitative influence on the tangent modulus relative to one material axis due to the presence of stresses in the other material axis is not known. This information is not available due to the lack of experimental data under biaxial stress states. Consequently the use of components of strains under biaxial stress fields to determine S_{ij} (ϵ_i) is erroneous. For the determination of the tangent moduli in this program the effect of the presence of transverse stresses (or longitudinal) is allowed for. For this purpose it is assumed that simple equivalent strain increments can be computed from the following Equations.

$$d\epsilon_1\Big|_{Eq.} = d\epsilon_1/(1-\nu_{12}B) \tag{2}$$

$$d\epsilon_2\Big|_{Eq.} = d\epsilon_2/(1-\nu_{21}/B) \tag{3}$$

where

ν_{12} = Major Poisson's Ratio and

$B = d\sigma_2/d\sigma_1$

3. In order to compute laminate strain increments, Equation 24 of Reference 1 is used. This Equation is

$$[d\epsilon^\circ] = [A]^{-1}\ [dN] \tag{4}$$

where $[d\varepsilon^\circ]$ = Laminate Strain Increments

$[A]^{-1}$ = Laminate Compliance Matrix

$[dN]$ = Increments of Stress Resultants

The compliance matrix $[A]^{-1}$ in Equation 4 represents the average compliance properties during the application of (n+1)-th load increment. However, these properties are not known beforehand. This difficulty is overcome by using the elastic properties corresponding to those at the end of the n-th load increment to compute laminate strain increments. These are then used to compute current stresses and strains in the plies. Based upon the current strains in the plies, average elastic properties are determined. A new compliance matrix is computed and laminate strain increments determined. This procedure is repeated until the difference between two laminate strain increments in two consecutive cycles is smaller than the prescribed error bound. This predictor-corrector and iterative procedure renders the method of analysis practically independent of the size of the load increment.

4. Incremental loading of the laminate cannot continue indefinitely without affecting the load carrying capability of the plies. To determine the onset of degradation of the plies, a criterion is used. The criterion used in this program (Equations 21, and 22 of Reference 2) is a function of both stress and strain states. Specialized for plane stress conditions, it can be written as

$$K_i \left[\int_{\hat{\varepsilon}_i} \sigma_i d\varepsilon_i\right]^{m_i} = 1 \quad (i = 1, 2, 6) \tag{5}$$

where

$$K_i = [\int_{\varepsilon_{iu}} \sigma_i d\varepsilon_i]^{-m_i} \quad (i = 1, 2, 6) \qquad (6)$$

In Equations 5 and 6, $\hat{\varepsilon}_i$, ε_{iu} are current and ultimate normal (tensile or compressive) and shear components of strains.

In plywise application of Equation 5, the program NOLAST allows for two modes of failure i.e. fiber failure and matrix failure modes. To distinguish between the two modes, it is assumed that if

$$K_1 [\int_{\hat{\varepsilon}_1} \sigma_1 d\varepsilon_1]^{m_1} \Big/ K_i [\int_{\hat{\varepsilon}_i} \sigma_i d\varepsilon_i]^{m_i} \geqslant 0.1 \qquad (7)$$

the failure mode of the ply corresponds to that of the fiber. When the ply reaches a degradation state, the ply is assumed to unload while the laminate loads are maintained. In the case of a matrix failure mode, both transverse and shear loads of the affected lamina are set to zero. If the failure corresponds to that of the fiber, total unloading of the affected plies is assumed.

5. Strain components corresponding to biaxial stress states are used to satisfy Equations 5 to 7, while equivalent strain components are used to determine tangent moduli. In the absence of experimental data, it is assumed that these strain components cannot be in excess of the ultimate strains obtained under simple load conditions. For this reason, these two type of strain components are checked at the end of application of each load increment. If the difference between ultimate

experimental strain components and equivalent and/or biaxial strain components is less than a prescribed value, the ply is assumed to have failed. The mode of failure would depend upon the nature of the strain component. The exceedance of longitudinal strains results in the fiber failure mode while the others cause a matrix mode of failure.

6. Once the ply failure and its associated mode have been established (Point B in Figure 1), there still remains a question of the influence of the failed ply upon the laminate. Some of the possible responses of the laminate subsequent to the initial ply failure are shown in Figure 1. They are the following:

a. The affected ply unloads completely at B giving rise to a instantaneous increase in strain BB_1 or a drop in stress BB_2 depending upon the nature loading process. Under constant loading rate, the path BB_1 would be obtained, while the path BB_2 would result under constant displacement application. After B_1 or B_2, the stress strain response would be along B_1A_1 or B_2A_2.

b. An other extreme response corresponding to paragraph 6.a. could be obtained by assuming that the ply continues to carry failure loads (Path BA_4) but can sustain no additional loads. This will correspond to an elastic perfectly plastic material.

c. Between the two extremes discussed in paragraphs 6.a. and 6.b., other paths could result depending upon the nature of unloading of the affected ply.

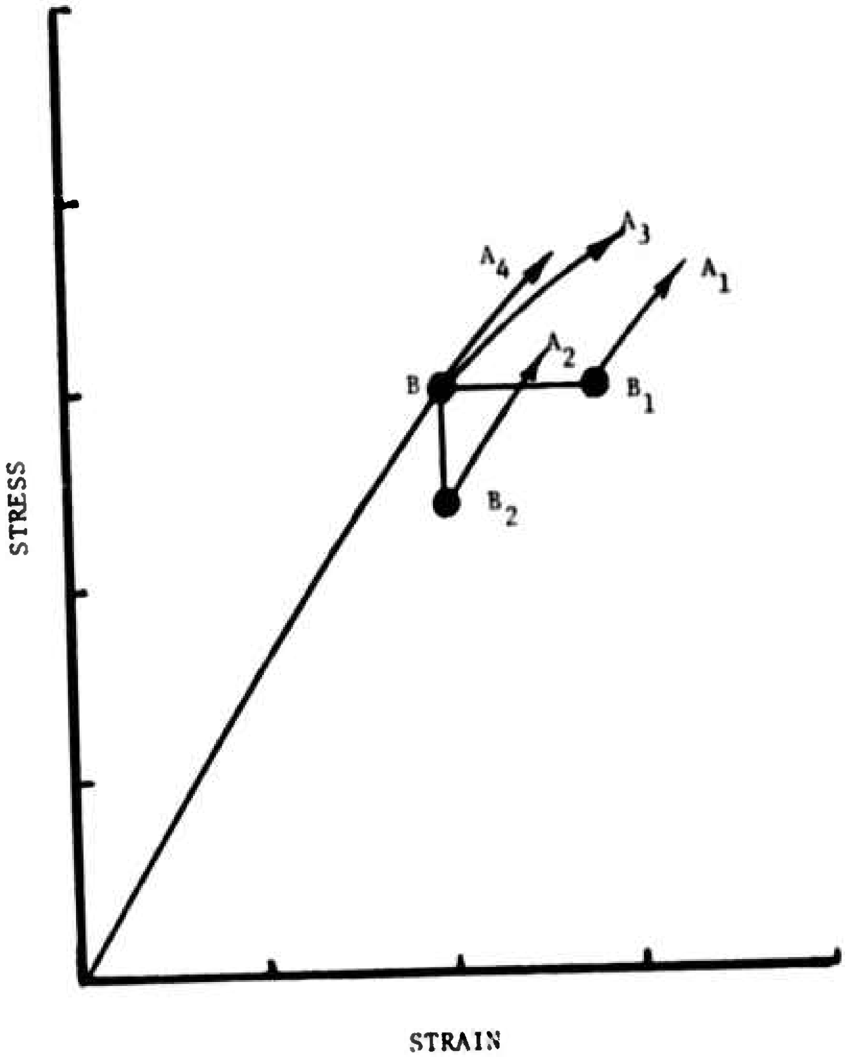

Figure 1. Laminate Response Subsequent to Initial Failure

d. The affected ply may unload gradually. This would correspond to the path BA_3.

In the NOLAST program, the unloading option of the affected ply corresponds to the path BB_1A_1. Introduction of other options into the program is not a problem. This is discussed in Section IV.

The structure of the program 'NOLAST' is shown in Figure 2. The main program calls Subroutines INPUT and SPLIN1 only once. Thereafter for every increment of loads, it calls Subroutines ELCON, ITER and OUTPUT in succession.

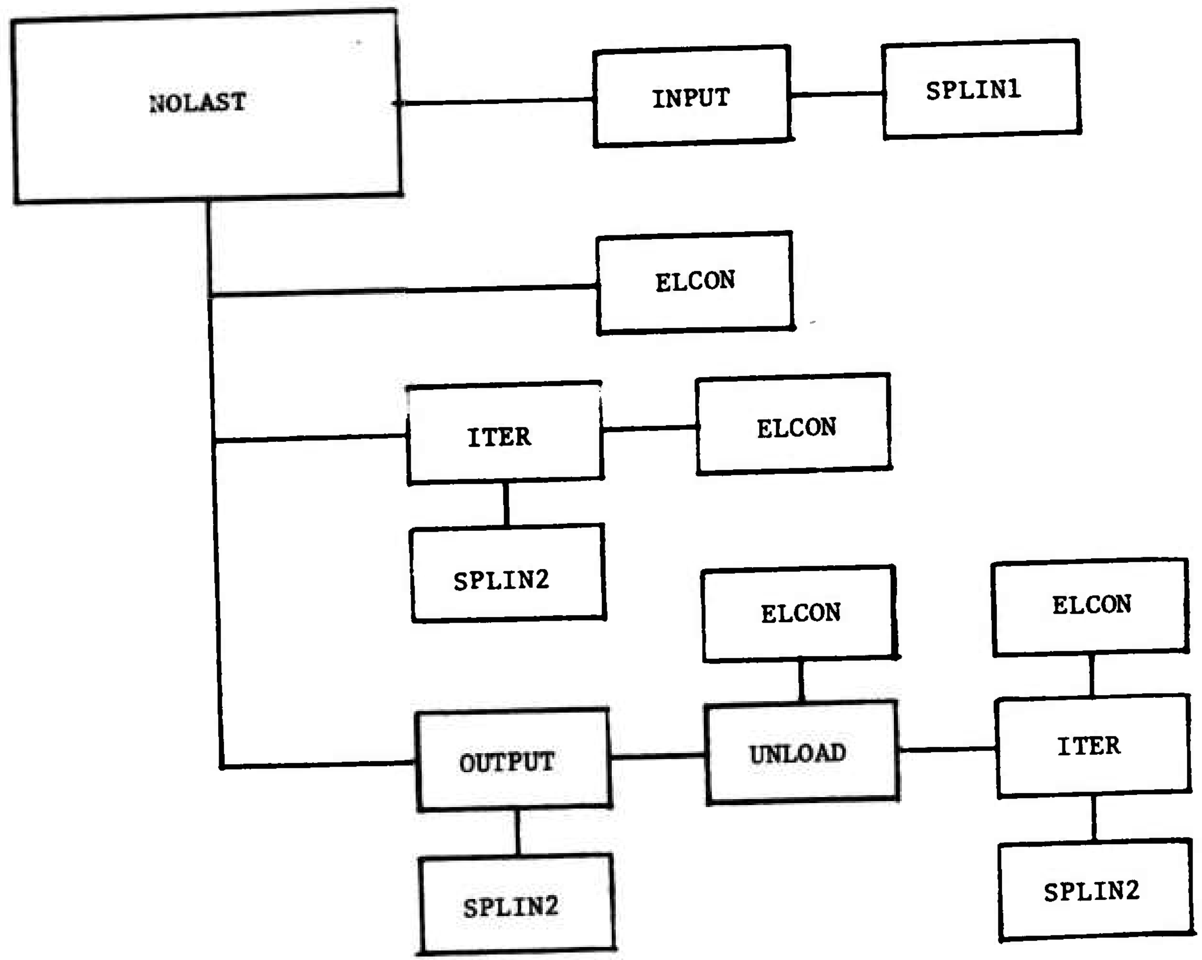

Figure 2. Computer Program Structure

SECTION III

USER'S INSTRUCTIONS FOR DATA PREPARATION

The following sequence of punched cards will be necessary for conducting strength analysis of laminates:

Card 1	HED CARD (12A6)		
Col	1-72 Any alphanumeric information		

Card 2	MATERIALS (I5)		
Col	1-5 MATYPE - number of material systems, (maximum = 5)		

Cards 3	NUMBER OF NODAL POINTS FOR STRESS-STRAIN PLOTS (7I5)		
Col	1-5	NEPOT	- 0° tensile
	6-10	NEPOC	- 0° compressive
	11-15	NEP90T	- 90° tensile
	16-20	NEP90C	- 90° compressive
	21-25	NIP12	- shear
	26-30	NPNUT	- tensile Poisson's ratio
	31-35	NPNUC	- Compressive Poisson's ratio

Note 1. The above nodal points data includes the fictitious nodal point A (Figure 3). This is done to improve the accuracy of the curves in the last segment. Maximum number of nodal points for a stress-strain plot is limited to 30.

Cards 4	MATERIAL PROPERTY DATA (6F10.0)		
Col	1-10	Strain	Repeat until all stress-strain
	11-20	Stress	data corresponding to 0° tension,
	21-30	Strain	0° compression, 90° tension, 90°
	31-40	Stress	compression, shear, tensile Poisson's
	41-50	Strain	ratio and compression Poisson's ratio
	51-60	Stress	in sequence is accounted for.

Cards 5	INITIAL ELASTIC PROPERTIES (6F10.0)		
Col	1-10	E1T	Elastic modulus of 0° lamina in tension
	11-20	E1C	Elastic modulus of 0° lamina in compression
	21-30	E2T	Elastic modulus of 90° lamina in tension
	31-40	E2C	Elastic modulus of 90° lamina in compression
	41-50	G12	Shear modulus of 0° lamina

Note 2. One set of (Cards 3 to 5) this data is required for each material system.

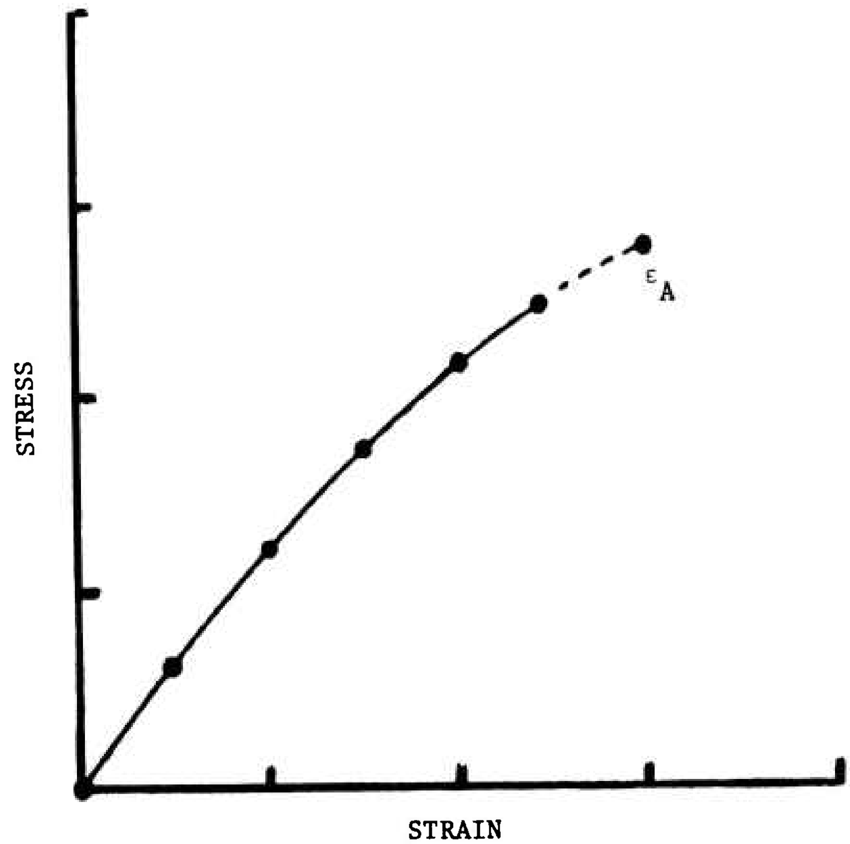

Figure 3. Fictitious Nodal Point A

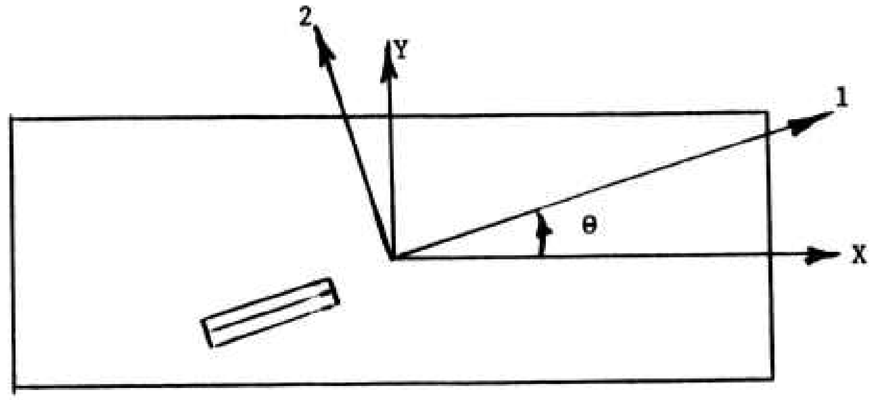

Figure 4. Transformation of Axes

Card 6	NUMBER OF LAMINATES (14I5)		
Col	1-5	NUMLAM	- number of laminates

Cards 7	CONTROL CARDS FOR EACH LAMINATE (14I5)		
Col	1-5	LAMINA	- number of plies in a laminate (maximum = 15)
	6-10	NN	- number of load combinations (maximum = 10)
	11-15	MLT	- Exponents in Equations 5 to 7. Until further experimentation, they may be assumed to be unity.
	16-20	MLC	-
	21-25	MTT	-
	26-30	MTC	-
	31-35	MSH	-
	36-40	NPRINT	- Print output for each NPRINT increment (e.g. if NPRINT = 3, the output would be printed 3rd, 6th, 9th etc. increments) except the output for first increment and every increment after initial failure.
	41-45	NOPSHN	- Unloading option. It is to be taken equal to unity until additional options of unloading are added. For NOPSHN = 1, the affected ply or plies are unloaded in one step and loads transferred to the remaining plies.

Cards 8	BOUNDARIES OF PLIES OF THE LAMINATE (6F10.0)		
Col	1-10	H(1)	These are the distances of the boundaries of the plies from a reference line as defined in Figure 5.
	11-20	H(2)	
	21-30	H(3)	
	31-40	H(4)	
		:	
		H(LAMINA + 1)	

Cards 9	ORIENTATION OF PLIES (6F10.0)		
Col	1-10	TH(1)	Orientation angle in degrees of the first ply (Figure 4)
	11-20	TH(2)	Orientation angle in degrees of the second ply (Figure 4)
		:	
		TH(LAMINA)	Orientation angle in degrees of the last ply (Figure 4)

Cards 10	MATERIAL TYPES ASSOCIATED WITH PLIES (14I5)		
Col	1-5	MAT(1)	Material number of the first ply
	6-10	MAT(2)	Material number of the second ply
		:	
		MAT(LAMINA)	Material number of the last ply

Cards 11	LOAD CONDITIONS (3F10.0)		
Col	1-10	A1(1)	Stress resultant ΔNX in x-direction (Figure 4) for the first load condition.
	11-20	A2(1)	Stress resultant ΔNY in y-direction (Figure 4) for the first load condition.
	21-30	A3(1)	Stress resultant ΔNXY in xy-direction (Figure 4) for the first load condition.

Note 3.1 Repeat for all the number of load conditions NN of the Card 7.

Note 3.2 The components of stress resultants are computed by estimating strengths (NX, NY, and NXY) of the laminate and dividing the same by the number of desired increments. Experience indicates that 10-20 increments are adequate.

Note 3.3 ΔNX, ΔNY, ΔNXY of Cards 11 represent the maximum size of the increments. In the program the increment size get reduced as the failure points based upon strains are approached.

Note 4. Prepare other sets of cards from Card 7 to Card 11 for other laminates defined by Card 6.

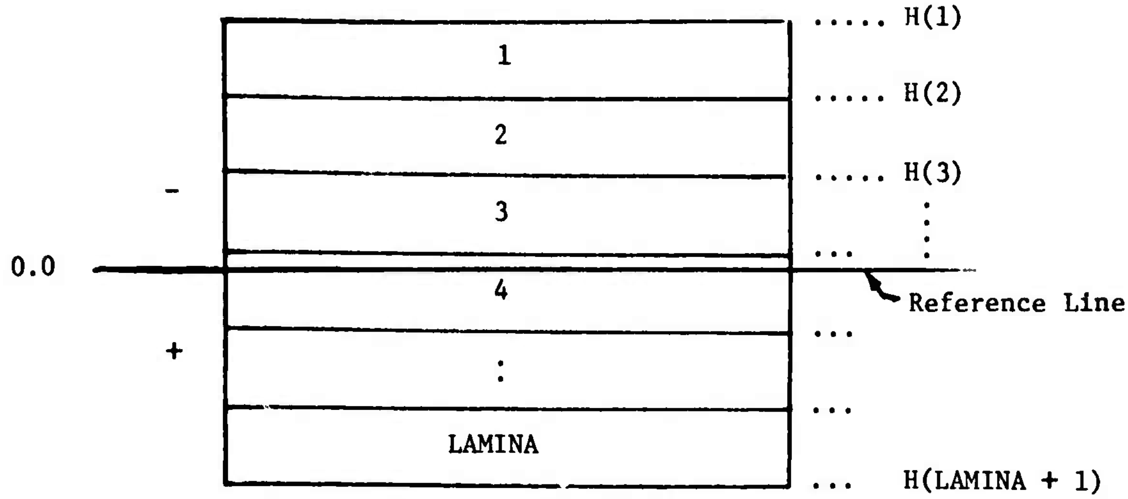

Figure 5. Distances of Boundaries of Plies of a Laminate from a Reference Line

SECTION IV

PROGRAM MODIFICATIONS AND SAMPLE PROBLEMS

1. MODIFICATIONS

NOLAST is the experimental computer program. It is being made available to designated recipients in the interest of timely exchange of technical information. Therefore user's experience communicated to AFFDL/FBR would be valuable for improving the program and would be appreciated. In the meantime, it is likely that the program would be modified by the users to suit their requirements. To help them in making modifications, the following comments are pertinent:

a. The program, in the present form, allows for five material systems (isotropic and anisotropic), thirty nodal points (including the fictitious one) of stress-strain curves, fifteen plies in a laminate, and ten combinations of loads for each of the laminates. These maxima can be modified by changing the dimensions of the program.

b. The program incorporates the criterion represented by Equations 5 to 7. Any other criterion, with constraints if any, may be introduced by insertion of suitable Fortran Statements in the Subroutine OUTPUT (cards 118 to 250).

c. Additional unloading options may be added to cards 373 and 374 by assigning a suitable number to NOPSHN on card 297 in the Subroutine OUTPUT.

d. For additional changes reference may be made to AFFDL/FBR.

2. SAMPLE PROBLEMS

In the present form, NOLAST is an in-core program requiring less than 60K octal. It was used to generate stress-strain responses of the following laminates reported herein:

a. $(0/\pm 45/90)_s$ laminate with all the plies of one material and subjected to two combinations of loads.

b. $(0/90)_{4s}$ laminate with all the plies of one material subjected to one load combination.

c. $(0/0/\pm 45/90)_s$ laminate with $(0/\pm 45/90)$ plies of one material and 0° ply of the second material subjected to one load combination.

Generation of the responses of the laminates (a, b, and c) required compilation and execution times of 8.28 seconds and 4.13 seconds respectively, on CYBER 7400 computer.

The stress-strain data of both materials appears on pages 49 and 50. The relevant input information for the three laminates (a, b, and c) is printed on pages 51, 58, and 63 respectively.

The output information on each of the printed pages consists of the following:

(i) Load Increment, Load Combination, Laminate No. and NOPSHN No.

(ii) Average laminate elastic constants (EX, EY, UXY, GXY, ETA1 and ETA2) during the load increment.

(iii) Components of the laminate strain increment.

(iv) Components of the laminate strain, stress resultant and stress.

(v) Components of biaxial lamina strains and stresses.

(vi) Components of equivalent lamina strains and corresponding stresses.

(vii) Total energies due only to longitudinal tension and compression, transverse tension and compression, and shear for each of the material systems. This information is printed only for the first load increment.

(viii) Energy ratios (longitudinal, transverse and shear), their sums for all plies and the sum of sums.

(ix) Moduli of elasticity of all plies at the end of the load increment.

(x) Information about failing plies and their modes.

(xi) At the time of the failure of a ply or plies (e.g. page 53, Load Increment 12, Load Combination 1, Laminate No. 1, NOPSHN No. 1) additional information consists of the moduli of elasticity of all the plies and stress resultants of the affected plies during unloading and iterative process. The unloading process was indicated by the total contribution (1.010665) of the fourth ply exceeding unity. The present program does not have a provision to refine the laminate stresses corresponding to the total contribution (1.010665) to those pertaining to the total contribution of unity. This can easily be done by interpolating the results of the current load increment and the previous one. These

remarks also apply to the final failure of the laminate.

(xii) Final failure of the laminate (e.g. page 55, Load Increment 18, Load Combination 1, Laminate No. 1, NOPSIN No. 1) occurs when the stress resultants of the failing plies cannot be imposed upon the intact plies without being reduced or without the stiffness matrix A becoming singular.

(xiii) Additional information about C_{ij} of the plies and A_{ij} of the laminate may be obtained by deleting the letter C in the beginning of the card numbers 245 and 247 of the Subroutine OUTPUT.

APPENDIX A

FORTRAN LISTING OF COMPUTER PROGRAM (NOLAST)

PROGRAM NOLAST

```
      PROGRAM NOLAST(INPUT,TAPE5=INPUT,OUTPUT,TAPE6=OUTPUT)
      COMMON/PROP/ NEP0T(5),EP0T(30,5),SIG0T(30,5),NEP0C(5),EP0C(30,5),
     1             SIG0C(30,5),NEP90T(5),EP90T(30,5),SIG90T(30,5),
     2             NEP90C(5),EP90C(30,5),SIG90C(30,5),NEP12(5),
     3             EP12(30,5),SIG12(30,5),NPNUT(5),EPNUT(30,5),
     4             PNUT(30,5),NPNUC(5),EPNUC(30,5),PNUC(30,5),
     5             SUM11(5),SUM12(5),SUM21(5),SUM22(5),SUM3(5),SUM0,
     6             E1T(5),E2T(5),G12(5),E1C(5),E2C(5),HED(12)
      COMMON/SPLN/ SP2(7,30,5),SP3(7,30,5),DELSY(7,30,5)
      COMMON/CNST/ MATYPE,NULAM,LAMINA,NN,NTURN,NFAIL,NOFF,LOAD,
     1             NTERM,EX,EY,UXY,GXY,VXY,WXY,SIGXX,SIGYY,SIGXY,
     2             EPXX,EPYY,EPXY,DA,EDIFF,KL,KM,MLT,MLC,MTT,MTC,MSH,
     3             NPRINT
      COMMON/MAIN/ H(16),TH(15),MAT(15),S1(15),S2(15),S3(15),S4(15),
     1             S5(15),S6(15),S7(15),S8(15),C(3,3,15),SIG(15,3),
     2             SIGDR(15,3),DELL(15),DETT(15),DELT(15),E11(15),
     3             E22(15),GG(15),UNN(15),SUMDLL(15),SUMDTT(15),
     4             SUMDLT(15),ENER(15,3),EPN(15,3),DEPN(15,3),
     5             STRESS(15,3),XX(15),XL(15),XT(15),XS(15),NLONG(15),
     6             NTRAN(15),NSHEAR(15),STRSS(15,3),A(3,3),DELEP(3),
     7             DLEP(3),A1(10),A2(10),A3(10),AA1(10),AA2(10),
     8             AA3(10),NALTER(15),STRAIN(15),SUM1(15),SUM2(15),
     9             SUMS(15),SIGDR1(15,3)
C
      REAL M(15),N(15)
      PRINT 100
  100 FORMAT(1HT)
      CALL INPUT(MATYPE)
      READ(5,50) NUMLAM
   50 FORMAT(14I5)
      KM=1
 1000 WRITE(6,60) KM
   60 FORMAT(1H1,//53X,13HLAMINATE NO. ,I2)
      READ(5,50) LAMINA,NN,MLT,MLC,MTT,MTC,MSH,NPRINT,NOPSHN
      KK=LAMINA+1
      READ(5,22) (H(K),K=1,KK)
   22 FORMAT(6F10.0)
      READ(5,22) (TH(K),K=1,LAMINA)
      READ(5,50) (MAT(K),K=1,LAMINA)
      READ(5,23) (A1(K),A2(K),A3(K),K=1,NN)
   23 FORMAT(3F10.0)
```

PROGRAM NOLAST

```
      WRITE(6,312) KK,(K,H(K),K=1,KK)
  312 FORMAT(15X,25HNO. OF BOUNDING SURFACES-,I5/
     1       (15X,11HDISTANCE OF,I4,11H-BOUNDARY -,F12.4))
      WRITE(6,602) (I,TH(I),MAT(I),I=1,LAMINA)
  602 FORMAT(//15X,6HLAMINA,4X,11HORIENTATION,4X,10HMATERIAL  /
     1       (17X,I2,7X,F8.3,8X,I2))
      WRITE(6,313) (I,A1(I),A2(I),A3(I),I=1,NN)
  313 FORMAT(//15X,32HLOAD COMBINATION ---------------,I4/
     1          15X,32HSTRESS RESULTANT INCREMENT NXX--,E17.8/
     2          15X,32HSTRESS RESULTANT INCREMENT NYY--,E17.8/
     3          15X,32HSTRESS RESULTANT INCREMENT NXY--,E17.8/)
      DO 700 I=1,NN
      AA1(I)=A1(I)
      AA2(I)=A2(I)
      AA3(I)=A3(I)
  700 CONTINUE

      DO 556 I=1,LAMINA
      TH(I)=TH(I)*3.14159265 36/180.
      M(I)=COS(TH(I))
      N(I)=SIN(TH(I))
      S1(I)=M(I)**4
      S2(I)=M(I)**2*N(I)**2
      S3(I)=M(I)**3*N(I)
      S4(I)=N(I)**4
      S5(I)=M(I)*N(I)**3
      S6(I)=M(I)**2
      S7(I)=N(I)**2
      S8(I)=M(I)*N(I)
  556 CONTINUE
      KL=1
      NETA=0
   20 LOAD=0
      NPR=0
      NFAIL=0
      SIGXX=0.
      SIGYY=0.
```

PROGRAM NOLAST

```
      SIGXY=0.
      EPXX=0.
      EPYY=0.
      EPXY=0.
      DO 330 I=1,LAMINA
      SUMOLL(I)=0.
      SUMOTT(I)=0.
      SUMOLT(I)=0.
      K=MAT(I)
      E11(I)=E1T(K)
      E22(I)=E2T(K)
      GG(I)=G12(K)
      UNN(I)=PNUT(1,K)
      NLONG(I)=0.
      NTRAN(I)=0
      NSHEAR(I)=0
      NALTER(I)=0
      DO 330 J=1,3
      DLEP(J)=0.
      ENER(I,J)=0.
      SIGOR1(I,J)=0.
      EPN(I,J)=0.
      DEPN(I,J)=0.
  330 CONTINUE
  801 CONTINUE
      CALL ELCON
      NOD=0
      NFRD=0
      IF(DA.LE.0.) GO TO 30
      CALL ITER
      IF(DA.LE.0.) GO TO 30
      CALL OUTPUT(NOPSHN,NPR)
      IF(NTERM.GE.LAMINA) GO TO 30
      IF(EDIFF.LE.0.) GO TO 30
      IF(DA.LE.0.) GO TO 30
      IF(NTURN-1) 801,30,801
   30 KL=KL+1
      IF(KL-NN) 20,20,40
   40 KM=KM+1
      IF(KM-NUMLAM) 1000,1000,45
   45 STOP
      END
```

SUBROUTINE INPUT

```
C
      SUBROUTINE INPUT(MATYPE)
      COMMON/PROP/ NEP0T(5),EP0T(30,5),SIG0T(30,5),NEP0C(5),EP0C(30,5),
     1             SIG0C(30,5),NEP90T(5),EP90T(30,5),SIG90T(30,5),
     2             NEP90C(5),EP90C(30,5),SIG90C(30,5),NEP12(5),
     3             EP12(30,5),SIG12(30,5),NPNUT(5),EPNUT(30,5),
     4             PNUT(30,5),NPNUC(5),EPNUC(30,5),PNUC(30,5),
     5             SUM11(5),SUM12(5),SUM21(5),SUM22(5),SUM3(5),SUM0,
     6             E1T(5),E2T(5),G12(5),E1C(5),E2C(5),HED(12)
      COMMON/SPLN/ SP2(7,30,5),SP3(7,30,5),DELSY(7,30,5)
C
      DIMENSION X(30),Y(30)
      READ(5,10) HED
   10 FORMAT(12A6)
      READ(5,19) MATYPE
   19 FORMAT(7I5)
      DO 1000 I=1,MATYPE
      READ(5,19)  NEP0T(I),NEP0C(I),NEP90T(I),NEP90C(I),NEP12(I),
     1            NPNUT(I),NPNUC(I)
      J1=NEP0T(I)
      J2=NEP0C(I)
      J3=NEP90T(I)
      J4=NEP90C(I)
      J5=NEP12(I)
      J6=NPNUT(I)
      J7=NPNUC(I)
      READ(5,20)  (EP0T(J,I),SIG0T(J,I),J=1,J1)
      READ(5,20)  (EP0C(J,I),SIG0C(J,I),J=1,J2)
      READ(5,20)  (EP90T(J,I),SIG90T(J,I),J=1,J3)
      READ(5,20)  (EP90C(J,I),SIG90C(J,I),J=1,J4)
      READ(5,20)  (EP12(J,I),SIG12(J,I),J=1,J5)
      READ(5,20)  (EPNUT(J,I),PNUT(J,I),J=1,J6)
      READ(5,20)  (EPNUC(J,I),PNUC(J,I),J=1,J7)
      READ(5,2 )  E1T(I),E1C(I),E2T(I),E2C(I),G12(I)
   2  FORMAT(6F1 ..)
      L=MAX0(J1,J2)
      L1=MAX0(J3,J4,J5)
      L2=MAX0(J6,J7)
      WRITE(6,30 )
  300 FORMAT(1H1)
```

SUBROUTINE INPUT

```
      WRITE(6,11) HED
   11 FORMAT(  12A6)
      WRITE(6,305) I
  305 FORMAT( /53X,8HMATERIAL,I2)
      WRITE(6,310) (EP0T(J,I),SIG0T(J,I),EP0C(J,I),SIG0C(J,I),J=1,L)
  310 FORMAT( /15X80H  STRAIN 0 DEG.(TEN)  STRESS 0 DEG.(TEN)  STRAIN 0
     1DEG.(COM)  STRESS 0 DEG.(COM)  /(15X,4E20.8))
      WRITE(6,315) (EP90T(J,I),SIG90T(J,I),EP90C(J,I),SIG90C(J,I),
     1              EP12(J,I),SIG12(J,I),J=1,L1)
  315 FORMAT( / 5X80H  STRAIN 90DEG.(TEN)  STRESS 90DEG.(TEN)  STRAIN 9
     1DEG.(COM)  STRESS 90DEG.(COM),8X,12HSHEAR STRAIN,9X,
     2  12HSHEAR STRESS  /(5X,6E2 .8))
      WRITE(6,325) (EPNUT(J,I),PNUT(J,I),EPNUC(J,I),PNUC(J,I),J=1,L2)
  325 FORMAT( /15X,80H  STRAIN 0 DEG.(TEN) TEN. POSSONS RATIO  STRAIN 0
     1DEG.(COM) COM. POSSONS RATIO    /(15X,4E20.8))
      WRITE(6,331) E1T(I),E1C(I),E2T(I),E2C(I),G12(I)
  331 FORMAT(15X,30HINITIAL MODULI OF ELASTICITY    /
     1        15X,6HE1T=,E15.8,6H  E1C=,E15.8,6H  E2T=,E15.8,
     2        6H  E2C=,E15.8,6H  G12=,E15.8)
      DO 801 J=1,J1
      X(J)=EP0T(J,I)
  801 Y(J)=SIG0T(J,I)
      CALL SPLIN1(J1,X,Y,1,XY,I)
      SUM11(I)=XY
      DO 802 J=1,J2
      X(J)=EP0C(J,I)
  802 Y(J)=SIG0C(J,I)
      CALL SPLIN1(J2,X,Y,2,XY,I)
      SUM12(I)=XY
      DO 803 J=1,J3
      X(J)=EP90T(J,I)
  803 Y(J)=SIG90T(J,I)
      CALL SPLIN1(J3,X,Y,3,XY,I)
      SUM22(I)=XY
      DO 804 J=1,J4
      X(J)=EP90C(J,I)
  804 Y(J)=SIG90C(J,I)
      CALL SPLIN1(J4,X,Y,4,XY,I)
      SUM21(I)=XY
```

SUBROUTINE INPUT

```
      DO 805 J=1,J5
C
      X(J)=EP12(J,I)
  805 Y(J)=SI 12(J,I)
      CALL SPLIN1(J5,X,Y,5,XY,I)
      SUM3(I)=XY
      DO 806 J=1,J6
      X(J)=EPNUT(J,I)
  806 Y(J)=PNUT(J,I)
      CALL SPLIN1(J6,X,Y,6,XY,I)
      DO 807 J=1,J7
      X(J)=EPNUC(J,I)
  807 Y(J)=PNUT(J,I)
      CALL SPLIN1(J7,X,Y,7,XY,I)
 1000 CONTINUE
      RETURN
      END
```

SUBROUTINE SPLIN1

```
C
      SUBROUTINE SPLIN1(N,X,Y,M,PROXIN,K)
      COMMON/SPLN/ SP2(7,30,5),SP3(7,30,5),DELSY(7,30,5)
C
      DIMENSION   X(N),Y(N),H(30),DELY(30),H2(30),B(30),DELSQY(30),
     1            C(30),S2(30),S3(30)
      EPSLN=0.1
    2 N1=N-1
    3 DO 51 I=1,N1
      H(I)=X(I+1)-X(I)
   51 DELY(I)=(Y(I+1)-Y(I))/H(I)
    4 DO 52 I=2,N1
      H2(I)=H(I-1)+H(I)
      B(I)=.5*H(I-1)/H2(I)
      DELSQY(I)=(DELY(I)-DELY(I-1))/H2(I)
      S2(I)=2.*DELSQY(I)
   52 C(I)=3.*DELSQY(I)
      S2(1)=0.
      S2(N)=0.
      OMEGA=1.0717968
    5 ETA=0.
    6 DO 10 I=2,N1
    7 W=(C(I)-B(I)*S2(I-1)-(.5-B(I))*S2(I+1)-S2(I))*OMEGA
    8 IF(ABS(W)-ETA) 10,10,9
    9 ETA=ABS(W)
   10 S2(I)=S2(I)+W
   13 IF(ETA-EPSLN) 14,5,5
   14 DO 53 I=1,N1
   53 S3(I)=(S2(I+1)-S2(I))/H(I)
      DO 100 I=1,N
      SP2(M,I,K)=S2(I)
      SP3(M,I,K)=S3(I)
      DELSY(M,I,K)=DELY(I)
  100 CONTINUE
   20 PROXIN=0.
      N1=N1-1
      DO 62 I=1,N1
   62 PROXIN=PROXIN+.5*H(I)*(Y(I)+Y(I+1))-H(I)**3*(S2(I)+S2(I+1))/24.
      RETURN
      END
```

SUBROUTINE ELCON

```
C
      SUBROUTINE ELCON
      COMMON/PROP/ NEP0T(5),EP0T(30,5),SIG0T(30,5),NEP0C(5),EP0C(30,5),
     1             SIG0C(30,5),NEP90T(5),EP90T(30,5),SIG90T(30,5),
     2             NEP90C(5),EP90C(30,5),SIG90C(30,5),NEP12(5),
     3             EP12(30,5),SIG12(30,5),NPNUT(5),EPNUT(30,5),
     4             PNUT(30,5),NPNUC(5),EPNUC(30,5),PNUC(30,5),
     5             SUM11(5),SUM12(5),SUM21(5),SUM22(5),SUM3(5),SUM.,
     6             E1T(5),E2T(5),G12(5),E1C(5),E2C(5),HED(12)
      COMMON/CNST/ MATYPE,NULAM,LAMINA,NN,NTURN,NFAIL,NOFF,LOAD,
     1             NTERM,EX,EY,UXY,GXY,VXY,WXY,SIGXX,SIGYY,SIGXY,
     2             EPXX,EPYY,EPXY,DA,EDIFF,KL,KM,MLT,MLC,MTT,MTC,MSH,
     3             NPRINT
      COMMON/MAIN/ H(16),TH(15),MAT(15),S1(15),S2(15),S3(15),S4(15),
     1             S5(15),S6(15),S7(15),S8(15),C(3,3,15),SIG(15,3),
     2             SIGDR(15,3),DELL(15),DETT(15),DELT(15),E11(15),
     3             E22(15),GG(15),UNN(15),SUMDLL(15),SUMDTT(15),
     4             SUMDLT(15),ENER(15,3),EPN(15,3),DEPN(15,3),
     5             STRESS(15,3),XX(15),XL(15),XT(15),XS(15),NLONG(15),
     6             NTRAN(15),NSHEAR(15),STRSS(15,3),A(3,3),DELEP(3),
     7             DLEP(3),A1(10),A2(10),A3(10),AA1(10),AA2(10),
     8             AA3(10),NALTER(15),STRAIN(15),SUM1(15),SUM2(15),
     9             SUMS(15),SIGDR1(15,3)
C
      DIMENSION X1(15),X2(15),X3(15),XX1(15),XX2(15),XX3(15)
      IF(NOFF.EQ.1) WRITE(6,652) (E11(I),E22(I),GG(I),UNN(I),I=1,LAMINA)
  652 FORMAT(30H  ELCON CALLED FROM *UNLOAD*        /
     1       30X,21HMODULI OF ELASTICITY      /(10X,4E20.8))
      IF(NOFF.EQ.1) WRITE(6,651) A1(KL),A2(KL),A3(KL)
  651 FORMAT(30X,18HSTRESS RESULTANTS       /(10X,3E20.8))
      NTURN=0
      NLIMIT=0
      KK=LAMINA+1
  801 DO 27 L=1,LAMINA
      IF(E11(L).EQ.0..OR.E22(L).EQ.0.)  GO TO 33
      UN=UNN(L)*E22(L)/E11(L)
      GO TO 32
   33 UN=0.
   32 UNU=1./(1.-UN*UNN(L))
      C11=E11(L)*UNU
```

SUBROUTINE ELCON

```
      C12=E22(L)*UNN(L)*UNU
      C16=0.
      C22=E22(L)*UNU
      C26=0.
      C66=G(L)
      C21=C12
      C61=C16
      C62=C26
      C(1,1,L)=S1(L)*C11+2.*S2(L)*C12+4.*S3(L)*C16+S4(L)*C22+4.*S5(L)
     1        *C26+4.*S2(L)*C66
      C(1,2,L)=S2(L)*C11+(S1(L)+S4(L))*C12+2.*(S5(L)-S3(L))*C16+S2(L)
     1        *C22+2.*(S3(L)-S5(L))*C26-4.*S2(L)*C66
      C(2,1,L)=C(1,2,L)
      C(1,3,L)=-S3(L)*C11+(S3(L)-S5(L))*C12+(S1(L)-3.*S2(L))*C16+S5(L)
     1        *C22+(3.*S2(L)-S4(L))*C26+2.*(S3(L)-S5(L))*C66
      C(3,1,L)=C(1,3,L)
      C(2,2,L)=S4(L)*C11+2.*S2(L)*C12-4.*S5(L)*C16+S1(L)*C22-
     1        4.*S3(L)*C26+4.*S2(L)*C66
      C(2,3,L)=-S5(L)*C11+(S5(L)-S3(L))*C12+(3.*S2(L)-S4(L))*C16+
     1        S3(L)*C22+(S1(L)-3.*S2(L))*C26+(S5(L)-S3(L))*2.*C66
      C(3,2,L)=C(2,3,L)
      C(3,3,L)=S2(L)*C11-2.*S2(L)*C12+2.*(S5(L)-S3(L))*C16
     1        +S2(L)*C22+2.*(S3(L)-S5(L))*C26+(S6(L)-S7(L))**2*C66
   27 CONTINUE
      DO 35 I=1,3
      DO 36 J=1,3
      A(I,J)=0.
      DO 37 K=1,LAMINA
      KO=K+1
      A(I,J)=A(I,J)+C(I,J,K)*(H(KO)-H(K))
   37 CONTINUE
   36 CONTINUE
   35 CONTINUE
      DA  =A(1,1)*(A(2,2)*A(3,3)-A(2,3)*A(3,2))+A(1,2)*(A(2,3)*A(3,1)-
     1    A(2,1)*A(3,3))+A(1,3)*(A(2,1)*A(3,2)-A(2,2)*A(3,1))
      IF(DA) 30,30,31
   31 CONTINUE
      AL11=(A(2,2)*A(3,3)-A(2,3)**2)/DA
      AL12=(A(1,3)*A(2,3)-A(1,2)*A(3,3))/DA
      AL13=(A(1,2)*A(2,3)-A(1,3)*A(2,2))/DA
```

SUBROUTINE ELCON

```
      AL21=AL12
      AL22=(A(1,1)*A(3,3)-A(1,3)**2)/DA
      AL23=(A(1,2)*A(1,3)-A(1,1)*A(2,3))/DA
      AL31=AL13
      AL32=AL23
      AL33=(A(1,1)*A(2,2)-A(1,2)**2)/DA
      HK=H(KK)-H(1)
      EX=1./(AL11*HK)
      EY=1./(AL22*HK)
      GXY=1./(AL33*HK)
      UXY=-AL12*EX*HK
      VXY=AL13*EX*HK
      WXY=AL23*EY*HK
      IF(NOFF.EQ.1) GO TO 100
      IF(NFAIL.EQ.0) GO TO 100
      DO 101 I=1,NN
      A1(I)=AA1(I)
      A2(I)=AA2(I)
      A3(I)=AA3(I)
  101 CONTINUE
      NFAIL=0
  100 CONTINUE
      DELEP(1)=A1(KL)*AL11+A2(KL)*AL12+A3(KL)*AL13
      DELEP(2)=A1(KL)*AL21+A2(KL)*AL22+A3(KL)*AL23
      DELEP(3)=A1(KL)*AL31+A2(KL)*AL32+A3(KL)*AL33
      DO 110 I=1,LAMINA
      SIG(I,1)=C(1,1,I)*DELEP(1)+C(1,2,I)*DELEP(2)+C(1,3,I)*DELEP(3)
      SIG(I,2)=C(2,1,I)*DELEP(1)+C(2,2,I)*DELEP(2)+C(2,3,I)*DELEP(3)
      SIG(I,3)=C(3,1,I)*DELEP(1)+C(3,2,I)*DELEP(2)+C(3,3,I)*DELEP(3)
      SIGOR(I,1)=SIG(I,1)*S6(I)+SIG(I,2)*S7(I)-2.*SIG(I,3)*S8(I)
      SIGOR(I,2)=SIG(I,1)*S7(I)+SIG(I,2)*S6(I)+2.*SIG(I,3)*S8(I)
      SIGOR(I,3)=SIG(I,1)*S6(I)-SIG(I,2)*S6(I)+SIG(I,3)*(S6(I)-S7(I))
      DELL(I)=DELEP(1)*S6(I)+DELEP(2)*S7(I)-DELEP(3)*S8(I)
      DETT(I)=DELEP(1)*S7(I)+DELEP(2)*S6(I)+DELEP(3)*S8(I)
      DELT(I)=DELEP(1)*2.*S8(I)-DELEP(2)*2.*S8(I)+DELEP(3)*(S6(I)-S7(I))
  110 CONTINUE
      ZZZ=0.
      DO 310 I=1,3
  310 ZZZ=ZZZ+DELEP(I)**2
      ZZZ=SQRT(ZZZ)
```

```
SUBROUTINE ELCON

      IF(ZZZ.GE.1.) DA=0.
      IF(ZZZ.GE.1.) GO TO 30
      DO 150 I=1,LAMINA
      K=MAT(I)
      K1=NEP0T(K)-1
      K2=NEP0C(K)-1
      K3=NEP90T(K)-1
      K4=NEP90C(K)-1
      K5=NEP12(K)-1
      T1T=EP0T(K1,K)
      T1C=EP0C(K2,K)
      T2T=EP90T(K3,K)
      T2C=EP90C(K4,K)
      T12=EP12(K5,K)
      XX1(I)=SUMDLL(I)+DELL(I)
      XX2(I)=SUMDTT(I)+DETT(I)
      XX3(I)=SUMDLT(I)+DELT(I)
      TT1=ABS(XX1(I))
      TT2=ABS(XX2(I))
      TT3=ABS(XX3(I))
      Y1=SIGDR(I,1)+SIGDR1(I,1)
      Y2=SIGDR(I,2)+SIGDR1(I,2)
      IF(E11(I).LE.0.) GO TO 150
      IF(ABS(SIGDR(I,1)).LE.0.1) B1=1.
      IF(ABS(SIGDR(I,1)).LE.0.1) GO TO 92
      B=SIGDR (I,2)/SIGDR (I,1)
      B1=(1.-UNN(I)*B)
   92 DEPN(I,1)=DELL(I)/B1
      X1(I)=EPN(I,1)+DEPN(I,1)
      T1=ABS(X1(I))
      IF(Y1) 70,71,71
   70 IF(T1.GE.T1C) GO TO 500
      IF(TT1.GE.T1C) GO TO 500
      GO TO 80
   71 IF(T1.GE.T1T) GO TO 500
      IF(TT1.GE.T1T) GO TO 500
   80 IF(E22(I).LE.0.) GO TO 150
      IF(ABS(SIGDR(I,1)).LE.0.1) B2=1.
      IF(ABS(SIGDR(I,1)).LE.0.1) GO TO 93
      IF(ABS(SIGDR(I,2)).LE.0.1) B2=1.
```

```
      SUBROUTINE ELCON

      IF(ABS(SIGDR(I,2)).LE.0.1) GO TO 93
      B2=(1.-UNN(I)*E22(I)/(E11(I)*B))
   93 DEPN(I,2)=DETT(I)/B2
      X2(I)=EPN(I,2)+DEPN(I,2)
      T2=ABS(X2(I))
      IF(Y2) 72,73,73
   72 IF(T2.GE.T2C) GO TO 500
      IF(TT2.GE.T2C) GO TO 500
      GO TO 81
   73 IF(T2.GE.T2T) GO TO 500
      IF(TT2.GE.T2T) GO TO 500
   81 IF(GG(I).LE.0.) GO TO 150
      DEPN(I,3)=DELT(I)
      X3(I)=EPN(I,3)+DEPN(I,3)
      T3=ABS(X3(I))
      IF(T3.GE.T12) GO TO 500
      IF(TT3.GE.T12) GO TO 500
  150 CONTINUE
      RETURN
  500 CONTINUE
      A1(KL)=0.5*A1(KL)
      A2(KL)=0.5*A2(KL)
      A3(KL)=0.5*A3(KL)
      NLIMIT=NLIMIT+1
      IF(NLIMIT-10)  400,400,40
   40 NTURN=1
  400 WRITE(6,104)
  104 FORMAT(10X,10HREDUCE       )
      IF(NOFF.EQ.1.AND.NLIMIT.GT.0) DA=0.
      IF(NOFF.EQ.1.AND.NLIMIT.GT.0) WRITE(6,200)
  200 FORMAT(///5X,48H *** UNLOADING LEADS TO FAILURE OF LAMINATE ***
     1            10X,20H PROGRAM TERMINATED         )
      RETURN
   30 WRITE(6,620) EX,EY,UXY,GXY,VXY,WXY
  620 FORMAT(//10X,3HEX=,E15.8,3X,3HEY=,E15.8,3X,4HUXY=,E15.8,3X,4HGXY=
     1      ,E15.8,//10X,5HETA1=,E15.8,3X,5HETA2=,E15.8,//
     2      10X, 25H MATRIX *A* IS SINGULAR       )
      RETURN
      END
```

SUBROUTINE ITER

```
C
      SUBROUTINE ITER
      COMMON/PROP/ NEP0T(5),EP0T(30,5),SIG0T(30,5),NEP0C(5),EP0C(30,5),
     1             SIG0C(30,5),NEP90T(5),EP90T(30,5),SIG90T(30,5),
     2             NEP90C(5),EP90C(30,5),SIG90C(30,5),NEP12(5),
     3             EP12(30,5),SIG12(30,5),NPNUT(5),EPNUT(30,5),
     4             PNUT(30,5),NPNUC(5),EPNUC(30,5),PNUC(30,5),
     5             SUM11(5),SUM12(5),SUM21(5),SUM22(5),SUM3(5),SUM0,
     6             E1T(5),E2T(5),G12(5),E1C(5),E2C(5),HED(12)
      COMMON/SPLN/ SP2(7,30,5),SP3(7,30,5),DELSY(7,30,5)
      COMMON/CNST/ MATYPE,NULAM,LAMINA,NN,NTURN,NFAIL,NOFF,LOAD,
     1             NTERM,EX,EY,UXY,GXY,VXY,WXY,SIGXX,SIGYY,SIGXY,
     2             EPXX,EPYY,EPXY,DA,EDIFF,KL,KM,MLT,MLC,MTT,MTC,MSH,
     3             NPRINT
      COMMON/MAIN/ H(16),TH(15),MAT(15),S1(15),S2(15),S3(15),S4(15),
     1             S5(15),S6(15),S7(15),S8(15),C(3,3,15),SIG(15,3),
     2             SIGOR(15,3),DELL(15),DETT(15),DELT(15),E11(15),
     3             E22(15),GG(15),UNN(15),SUMDLL(15),SUMDTT(15),
     4             SUMDLT(15),ENER(15,3),EPN(15,3),DEPN(15,3),
     5             STRESS(15,3),XX(15),XL(15),XT(15),XS(15),NLONG(15),
     6             NTRAN(15),NSHEAR(15),STRSS(15,3),A(3,3),DELEP(3),
     7             DLEP(3),A1(10),A2(10),A3(10),AA1(10),AA2(10),
     8             AA3(10),NALTER(15),STRAIN(15),SUM1(15),SUM2(15),
     9             SUMS(15),SIGOR1(15,3)
C
       DIMENSION X1(2),X2(2),X3(2),XX1(2),XX2(2),XX3(2),
     1           EE1(15),EE2(15),GG12(15),UNU(15),
     2          Y1(15),Y2(15),Y3(15),T(2),ST(2),SST(2),PT(2),
     3           PST(2),PSST(2),X(30),Y(30)
  101 ZD1=0.
      DO 100 I=1,3
      ZB=(1000.*DELEP(I))
      ZD1=ZD1+ZB*ZB
  100 CONTINUE
      MM=0
      ZD1=SQRT(ZD1)
  102 DO 130 I=1,LAMINA
      IF(NOFF.EQ.1.AND.MM.GE.6) GO TO 125
      IF(E11(I).LE.0.) GO TO 130
      Y1(I)=SIGOR(I,1)+SIGOR1(I,1)
```

SUBROUTINE ITER

```
      Y2(I)=SIGDR(I,2)+SIGDR1(I,2)
      Y3(I)=SIGDR(I,3)+SIGDR1(I,3)
      IF(ABS(SIGDR(I,1)).LE.0.1) B1=1.
      IF(ABS(SIGDR(I,1)).LE.0.1) GO TO 92
      B=SIGDR (I,2)/SIGDR (I,1)
      B1=(1.-UNN(I)*B)
   92 DEPN(I,1)=DELL(I)/B1
      XX1(1)=EPN(I,1)+DEPN(I,1)*0.5
      X1(1)=EPN(I,1)+DEPN(I,1)
      T(1)=ABS(XX1(1))
      T(2)=ABS(X1(1))
      K=MAT(I)
      IF(Y1(I)) 70,200,71
   70 KP=NEPOC(K)
      DO 201 J=1,KP
      X(J)=EPOC(J,K)
  201 Y(J)=SIGOC(J,K)
      SGN=-1.
      CALL SPLIN2(KP,X,Y,2,T,ST,SST,2,ZY,1,K)
      IF(E22(I).EQ.0.) GO TO 200
      KP=NPNUC(K)
      DO 202 J=1,KP
      X(J)=EPNUC(J,K)
  202 Y(J)=PNUC(J,K)
      CALL SPLIN2(KP,X,Y,2,T,PST,PSST,7,ZY,1,K)
      GO TO 73
   71 KP=NEPOT(K)
      DO 203 J=1,KP
      X(J)=EPOT(J,K)
  203 Y(J)=SIGOT(J,K)
      SGN=1.
      CALL SPLIN2(KP,X,Y,2,T,  ST,SST,1,ZY,1,K)
      IF(E22(I).EQ.0.) GO TO 200
      KP=NPNUT(K)
      DO 204 J=1,KP
      X(J)=EPNUT(J,K)
  204 Y(J)=PNUT(J,K)
      CALL SPLIN2(KP,X,Y,2,T,PST,PSST,6,ZY,1,K)
   73 E11(I)=SST(1)
      STRESS (I,1) =ST(2)*SGN
```

SUBROUTINE ITER

```
      IF(ABS(STRESS(I,1)).LE.0.1) STRESS(I,1)=0.
      EE1(I)=SST(2)
      IF(E22(I).LE.0.) GO TO 200
      UNU(I)=PST(2)
      UNN(I)=PST(1)
  200 CONTINUE
      IF(E22(I).LE.0.) GO TO 131
      IF(ABS(SIGDR(I,1)).LE.0.1) B2=1.
      IF(ABS(SIGDR(I,1)).LE.0.1) GO TO 93
      IF(ABS(SIGDR(I,2)).LE.0.1) B2=1.
      IF(ABS(SIGDR(I,2)).LE.0.1) GO TO 93
      B2=(1.-UNN(I)*E22(I)/(E11(I)*B))
   93 DEPN(I,2)=DETT(I)/B2
      XX2(1)=EPN(I,2)+DEPN(I,2)*0.5
      X2(1)=EPN(I,2)+DEPN(I,2)
      T(1)=ABS(XX2(1))
      T(2)=ABS(X2(1))
      IF(Y2(I)) 75,131,76
   75 KP=NEP90C(K)
      DO 205 J=1,KP
      X(J)=EP90C(J,K)
  205 Y(J)=SIG90C(J,K)
      SGN=-1.
      CALL SPLIN2(KP,X,Y,2,T,ST,SST,4,ZY,1,K)
      GO TO 77
   76 KP=NEP90T(K)
      DO 206 J=1,KP
      X(J)=EP90T(J,K)
  206 Y(J)=SIG90T(J,K)
      SGN=1.
      CALL SPLIN2(KP,X,Y,2,T,ST,SST,3,ZY,1,K)
   77 E22(I)=SST(1)
      STRESS (I,2) =ST(2)*SGN
      IF(ABS(STRESS(I,2)).LE.0.1) STRESS(I,2)=0.
      EE2(I)=SST(2)
  131 IF(GG(I).LE.0.) GO TO 130
      DEPN(I,3)=DELT(I)
      XX3(1)=EPN(I,3)+DEPN(I,3)*0.5
      X3(1)=EPN(I,3)+DEPN(I,3)
      T(1)=ABS(XX3(1))
```

SUBROUTINE ITER

```
      T(2)=ABS(X3(1))
      IF(Y3(I).EQ.0.) GO TO  130
      KP=NEP12(K)
      DO 207 J=1,KP
      X(J)=EP12(J,K)
  207 Y(J)=SIG12(J,K)
      CALL SPLIN2(KP,X,Y,2,T,ST,SST,5,ZY,1,K)
      STRESS (I,3) =ST(2)*Y3(I)/ABS(Y3(I))
      IF(ABS(STRESS(I,3)).LE.0.1) STRESS(I,3)=..
      GG(I)=SST(1)
      GG12(I)=SST(2)
  130 CONTINUE
      MM=MM+1
      CALL ELCON
      IF(DA.LE.0.) RETURN
      ZD2=0.
      DO 85 I=1,3
      ZB=(1000.*DELEF(I))
      ZD2=ZD2+ZB*ZB
   85 CONTINUE
      ZD2=SQRT(ZD2)
      DCHEK=ABS(ZD1-ZD2)
      RATIO=DCHEK/ZD1
      ZD1=ZD2
      IF(RATIO.LE.0.001.OR.MM.GE.10) GO TO 125
      GO TO 102
  125 DO 150 I=1,LAMINA
      IF(E11(I).LE.0.) GO TO 150
      IF(Y1(I).EQ.0.) GO TO  150
      UNN(I)=UNU(I)
      E11(I)=EE1(I)
      IF(E22(I).EQ.0..AND.NOFF.EQ.1) UNN(I)=0.
      IF(E22(I).LE.0.) GO TO 150
      IF(Y2(I).EQ.0.) GO TO  150
      E22(I)=EE2(I)
      IF(Y3(I).EQ.0.) GO TO  150
      GG(I)=GG12(I)
  150 CONTINUE
      RETURN
      END
```

SUBROUTINE SPLIN2

```
C
      SUBROUTINE SPLIN2(N,X,Y,M,T,SS,SS1,L,PROXIN,NI,K)
      COMMON/SPLN/ SP2(7,30,5),SP3(7,30,5),DELSY(7,30,5)
      DIMENSION   X(N),Y(N),T(M),SS(M ),SS1(M ),SS2(30)
C
      PROXIN=0.
   15 DO 61 J=1,M
   16 I=1
   54 IF(T(J)-X(1)) 58,17,55
   55 IF(T(J)-X(N)) 57,59,58
   56 IF(T(J)-X(I)) 60,17,57
   57 I=I+1
      GO TO 56
   58 WRITE(6,44) T(J),NI,X(N)
   44 FORMAT(15X,24H***ARGUMENT OUT OF RANGE,F15.8,2X,11HCALLED FROM,I4
     1            ,7H  X(N)=,F15.8)
      GO TO 61
   59 I=N
   60 I=I-1
   17 HT1=T(J)-X(I)
      HT2=T(J)-X(I+1)
      PROD=HT1*HT2
      SS2(J)=SP2(L,I,K)+HT1*SP3(L,I,K)
      DELSQS=(SP2(L,I,K)+SP2(L,I+1,K)+SS2(J))/6.
      SS(J)=Y(I)+HT1*DELSY(L,I,K)+PROD*DELSQS
      SS1(J)=DELSY(L,I,K)+(HT1+HT2)*DELSQS+PROD*SP3(L,I,K)/6.
   61 CONTINUE
      IF(M.GT.1) RETURN
      I=1
   10 IF(T(M) -X(I))  80,80,81
   81 HT1=X(I+1)-X(I)
      YY=Y(I+1)+Y(I)
      YZ=SP2(L,I,K)+SP2(L,I+1,K)
      PROXIN=PROXIN+0.5*HT1*YY-HT1**3*YZ/24.
      I=I+1
      GO TO 10
   80 HT1=X(I)-T(M)
      YY=Y(I)+SS(M)
      YZ=SP2(L,I,K)+SS2(M)
      PROXIN=PROXIN-0.5*HT1*YY+HT1**3*YZ/24.
      RETURN
      END
```

SUBROUTINE OUTPUT

```
      C
            SUBROUTINE OUTPUT(NOPSHN,NPR)
            COMMON/PROP/ NEP0T(5),EP0T(30,5),SIG0T(30,5),NEP0C(5),EP0C(30,5),
           1             SIG0C(30,5),NEP90T(5),EP90T(30,5),SIG90T(30,5),
           2             NEP90C(5),EP90C(30,5),SIG90C(30,5),NEP12(5),
           3             EP12(30,5),SIG12(30,5),NPNUT(5),EPNUT(30,5),
           4             PNUT(30,5),NPNUC(5),EPNUC(30,5),PNUC(30,5),
           5             SUM11(5),SUM12(5),SUM21(5),SUM22(5),SUM3(5),SUM.,
           6             E1T(5),E2T(5),G12(5),E1C(5),E2C(5),HED(12)
            COMMON/SPLN/ SP2(7,30,5),SP3(7,30,5),DELSY(7,30,5)
            COMMON/CNST/ MATYPE,NULAM,LAMINA,NN,NTURN,NFAIL,NOFF,LOAD,
           1             NTERM,EX,EY,UXY,GXY,VXY,WXY,SIGXX,SIGYY,SIGXY,
           2             EPXX,EPYY,EPXY,DA,EDIFF,KL,KM,MLT,MLC,MTT,MTC,MSH,
           3             NPRINT
            COMMON/MAIN/ H(16),TH(15),MAT(15),S1(15),S2(15),S3(15),S4(15),
           1             S5(15),S6(15),S7(15),S8(15),C(3,3,15),SIG(15,3),
           2             SIGDR(15,3),DELL(15),DETT(15),DELT(15),E11(15),
           3             E22(15),GG(15),UNN(15),SUMDLL(15),SUMDTT(15),
           4             SUMDLT(15),ENER(15,3),EPN(15,3),DEPN(15,3),
           5             STRESS(15,3),XX(15),XL(15),XT(15),XS(15),NLONG(15),
           6             NTRAN(15),NSHEAR(15),STRSS(15,3),A(3,3),DELEP(3),
           7             DLEP(3),A1(10),A2(10),A3(10),AA1(10),AA2(10),
           8             AA3(10),NALTER(15),STRAIN(15),SUM1(15),SUM2(15),
           9             SUMS(15),SIGDR1(15,3)
      C
            DIMENSION NSIGN1(3),NSIGN2(3),X(30),Y(30),T(2),ST(2),SST(2)
         20 LOAD=LOAD+1
            DO 110 I=1,LAMINA
            K=MAT(I)
            SIGDR1(I,1)=SIGDR(I,1)+SIGDR1(I,1)
            SIGDR1(I,2)=SIGDR(I,2)+SIGDR1(I,2)
            SIGDR1(I,3)=SIGDR(I,3)+SIGDR1(I,3)
            IF(ABS(SIGDR1(I,1)).LE.0.1) SIGDR1(I,1)=0.
            IF(ABS(SIGDR1(I,2)).LE.0.1) SIGDR1(I,2)=0.
            IF(ABS(SIGDR1(I,3)).LE.0.1) SIGDR1(I,3)=0.
            SUMDLL(I)=SUMDLL(I)+DELL(I)
            SUMDTT(I)=SUMDTT(I)+DETT(I)
            SUMDLT(I)=SUMDLT(I)+DELT(I)
            IF(E11(I).GT.0.) STRSS(I,1)=SIGDR1(I,1)
            IF(E22(I).GT.0.) STRSS(I,2)=SIGDR1(I,2)
```

SUBROUTINE OUTPUT

```
      IF(GG(I).GT.0.) STRSS(I,3)=SIGDR1(I,3)
      IF(E11(I).LE.0.) GO TO 110
      T(1)=ABS(SUMDLL(I))
      IF(SIGDR1(I,1)) 45,200,46
   45 KP=NEP0C(K)
      DO 701 J=1,KP
      X(J)=EP0C(J,K)
  701 Y(J)=SIG0C(J,K)
      M1=MLC
      CALL SPLIN2(KP,X,Y,1,T,ST,SST,2,ZY,2,K)
      SUM1(I)=SUM12(K)
      GO TO 73
   46 KP=NEP0T(K)
      DO 702 J=1,KP
      X(J)=EP0T(J,K)
  702 Y(J)=SIG0T(J,K)
      M1=MLT
      CALL SPLIN2(KP,X,Y,1,T,ST,SST,1,ZY,2,K)
      SUM1(I)=SUM11(K)
   73 ENER(I,1)=ZY
      GO TO 201
  200 SUM1(I)=SUM11(K)
  201 IF(E22(I).EQ.0.) DEPN(I,2)=DETT(I)
      IF(E22(I).EQ.0.) DEPN(I,1)=DELL(I)
      IF(E22(I).LE.0.) GO TO 111
      T(1)=ABS(SUMDTT(I))
      IF(SIGDR1(I,2)) 75,112,76
   75 KP=NEP90C(K)
      DO 703 J=1,KP
      X(J)=EP90C(J,K)
  703 Y(J)=SIG90C(J,K)
      M2=MTC
      CALL SPLIN2(KP,X,Y,1,T,ST,SST,4,ZY,2,K)
      SUM2(I)=SUM21(K)
      GO TO 77
   76 KP=NEP90T(K)
      DO 704 J=1,KP
      X(J)=EP90T(J,K)
  704 Y(J)=SIG90T(J,K)
      M2=MTT
```

SUBROUTINE OUTPUT

```
      CALL SPLIN2(KP,X,Y,1,T,ST,SST,3,ZY,2,K)
      SUM2(I)=SUM22(K)
   77 ENER(I,2)=ZY
      GO TO 111
  112 SUM2(I)=SUM22(K)
  111 IF( GG(I).EQ.0.) DEPN(I,3)=DELT(I)
      IF( GG(I).LE.0.) GO TO 110
      T(1)=ABS(SUMDLT(I))
      SUMS(I)=SUM3(K)
      IF(SIGOR1(I,3).EQ.0.) GO TO 110
      KP=NEP12(K)
      DO 705 J=1,KP
      X(J)=EP12(J,K)
  705 Y(J)=SIG12(J,K)
      M3=MSH
      CALL SPLIN2(KP,X,Y,1,T,ST,SST,5,ZY,2,K)
      ENER(I,3)=ZY
  110 CONTINUE
      DO 60 I=1,LAMINA
      DO 60 J=1,3
      EPN(I,J)=EPN(I,J)+DEPN(I,J)
   60 CONTINUE
      EFF1=2./SQRT(3.)*(EPXX*EPXX+EPYY*EPYY+EPXX*EPYY+0.25*EPXY*EPXY)**
     1 0.5
      EPXX=EPXX+DELEP(1)
      EPYY=EPYY+DELEP(2)
      EPXY=EPXY+DELEP(3)
      EFF2=2./SQRT(3.)*(EPXX*EPXX+EPYY*EPYY+EPXX*EPYY+0.25*EPXY*EPXY)**
     1 0.5
      EDIFF=EFF2-EFF1
      SIGXX=SIGXX+A1(KL)
      SIGYY=SIGYY+A2(KL)
      SIGXY=SIGXY+A3(KL)
  511 HK=H(LAMINA+1)-H(1)
      SGXX=SIGXX/HK
      SGYY=SIGYY/HK
      SGXY=SIGXY/HK
      DO 78 I=1,LAMINA
      K=MAT(I)
      K1=NEPOT(K)-1
```

SUBROUTINE OUTPUT

```
      K2=NEP0C(K)-1
      K3=NEP90T(K)-1
      K4=NEP90C(K)-1
      K5=NEP12(K)-1
      T1T=EP0T(K1,K)
      T1C=EP0C(K2,K)
      T2T=EP90T(K3,K)
      T2C=EP90C(K4,K)
      T12=EP12(K5,K)
      T1=ABS(EPN(I,1))
      T2=ABS(EPN(I,2))
      T3=ABS(EPN(I,3))
      TT1=ABS(SUMDLL(I))
      TT2=ABS(SUMDTT(I))
      TT3=ABS(SUMDLT(I))
      IF(E11(I).EQ.0.) GO TO 78
       XL(I)=ENER(I,1)/SUM1(I)
      IF(GG(I).EQ.0.) GO TO 7
      XS(I)=ENER(I,3)/SUMS(I)
    7 IF(E22(I).EQ.0.) GO TO 8
       XT(I)=ENER(I,2)/SUM2(I)
    8 IF(XL(I).EQ.0.) GO TO 2
      XL(I)=XL(I)**M1
    2 IF(XT(I).EQ.0.) GO TO 3
      XT(I)=XT(I)**M2
      IF(XT(I).LE.0.) XT(I)=0.
    3 IF(XS(I).EQ.0.) GO TO 4
      XS(I)=XS(I)**M3
      IF(XS(I).LE.0.) XS(I)=0.
    4  XX(I)=XL(I)+XT(I)+XS(I)
      IF(XX(I)-1.) 402,79,79
   79 NFAIL=NFAIL+1
      XR=XL(I)/XX(I)
      IF(XR-0.1) 240,250,250
  250 CONTINUE
      NLONG(I)=I
      E11(I)=0.
      UNN(I)=0.
  240 CONTINUE
      UNN(I)=0.
```

SUBROUTINE OUTPUT

```
      E22(I)=0.
      NTRAN(I)=I
      NSHEAR(I)=I
      SG(I)=0.
      NPR=1
      NALTER(I)=1
      GO TO 73
  402 IF(NLONG(I).EQ.I) GO TO  208
      IF(SIGDR1(I,1))202,204,204
  202 TX=ABS(T1-T1C)
      TXX=ABS(TT1-T1C)
      TXXT=TXX/T1C
      TXT=TX/T1C
      IF(TXT-0.001) 206,206,228
  228 IF(TXXT-0.001) 206,206,208
  204 TX=ABS(T1-T1T)
      TXT=TX/T1T
      TXX=ABS(TT1-T1T)
      TXXT=TXX/T1T
      IF(TXT.LE.0.001) GO TO 206
      IF(TXXT.GT.0.001) GO TO 208
  206 NLONG(I)=I
      E11(I)=0.
      E22(I)=0.
      SG(I)=0.
      UNN(I)=0.
      NALTER(I)=1
      NPR=1
      GO TO 400
  208 IF(NTRAN(I).EQ.I) GO TO 216
      IF(SIGDR1(I,2))210,212,212
  210 TY=ABS(T2-T2C)
      TYT=TY/T2C
      TYY=ABS(TT2-T2C)
      TYYT=TYY/T2C
      IF(TYT-0.001)  214,214,226
  226 IF(TYYT-0.001) 214,214,216
  212 TY=ABS(T2-T2T)
      TYT=TY/T2T
      TYY=ABS(TT2-T2T)
```

SUBROUTINE OUTPUT

```
      TYYT=TYY/T2T
      IF(TYT.LE.0.001) GO TO 214
      IF(TYYT.GE.0.001) GO TO 216
  214 NTRAN(I)=I
      UNN(I)=0.
      E22(I)=0.
      GG(I)=0.
      NALTER(I)=1
       NSHEAR(I)=I
      NFAIL=NFAIL+1
      NPR=1
  216 IF(NSHEAR(I).EQ.I) GO TO 78
      IF(GG(I).EQ.0.) GO TO 78
      TXY=ABS(T3-T12)
      TXYT=TXY/T12
      TXXY=ABS(TT3-T12)
      TXXYT=TXXY/T12
      IF(T3.EQ.0.) GO TO 78
      IF(TXYT-0.001) 215,215,230
  230 IF(TXXYT-0.001) 215,215,78
  215 NSHEAR(I)=I
      NALTER(I)=1
      NTRAN(I)=I
      GG(I)=0.
      E22(I)=0.
      UNN(I)=0.
      NPR=1
  400 NFAIL=NFAIL+1
   78 CONTINUE
      ENTLE=0.
      DO 178 I=1,LAMINA
  178 ENTLE=ENTLE+XX(I)
      LB=MOD(LOAD,NPRINT)
      IF(LOAD.EQ.1) GO TO 80
      IF(NPR.EQ.1) GO TO 80
      IF(LB) 800,80,800
   80 WRITE(6,300)
  300 FORMAT(1H1)
      WRITE(6,314)
  314 FORMAT(119X/119X)
```

SUBROUTINE OUTPUT

```
   99 FORMAT(15H  LAYER FAILING  ,3I10)
      WRITE(6,500) LOAD,KL,KM,NOPSHN
  500 FORMAT(10X,16HLOAD INCREMENT     ,I4,6X,16HLOAD COMBINATION   ,I4,
     1       6X,12HLAMINATE NO.   ,I2,6X,11HNOPSHN NO. ,I2)
C     WRITE(6,1000) (((C(I,J,L),J=1,3),I=1,3),L=1,LAMINA)
 1000 FORMAT(4X,9E13.4)
C     WRITE(6,1000) ((A(I,J),J=1,3),I=1,3)
      WRITE(6,620) EX,EY,UXY,GXY,VXY,WXY
  620 FORMAT( /10X,3HEX=,E15.8,3X,3HEY=,E15.8,3X,4HUXY=,E15.8,3X,4HGXY=
     1       ,E15.8,//10X,5HETA1=,E15.8,3X,5HETA2=,E15.8,/ )
      WRITE(6,353) (DELEP(I),I=1,3)
  353 FORMAT(11H  ST. INCR.,3X,8HDELEP(1),10X,8HDELEP(2),10X,8HDELEP(3),
     1       /7X,3E18.8,/ )
      WRITE(6,900)  EPXX,EPYY,EPXY,SIGXX,SIGYY,SIGXY
  900 FORMAT( /46X,42HSTRAINS - STRESS RESULTANTS / STRESSES        /
     1       13X,9HSTRAIN-XX,9X,9HSTRAIN-YY,9X,9HSTRAIN-XY,9X,
     2       9HRESUL.-XX,9X,9HRESUL.-YY,9X,9HRESUL.-XY,    /
     3       7X,6E18.8,/ )
      WRITE(6,370) SGXX,SGYY,SGXY
  370 FORMAT(61X,3E18.8/)
      WRITE(6,354)   (I,SUMDLL(I),SUMDTT(I),SUMDLT(I),(SIGDR1(I,J),
     1               J=1,3),I=1,LAMINA)
  354 FORMAT(7H  LAYER,6X,9HSTRAIN-LL,9X,9HSTRAIN-TT,9X,9HSTRAIN-LT,
     1       9X,9HSTRESS-LL,9X,9HSTRESS-TT,9X,9HSTRESS-LT,  /
     2       (3X,I2,2X,6E18.8))
      WRITE(6,901)   (I,(EPN(I,J),J=1,3),(STRESS(I,J),J=1,3),I=1,LAMINA)
  901 FORMAT(/10X,40HSTRESSES IN LAMINAE OBTAINED FROM STRESS ,
     1       14H-STRAIN CURVES        /
     2       7H  LAYER,6X,9HSTRAIN-L ,9X,9HSTRAIN-T ,9X,9HSTRAIN-LT,
     3       9X,9HSTRESS-L ,9X,9HSTRESS-T ,9X,9HSTRESS-LT,  /
     4       (3X,I2,2X,6E18.8))
      IF(LOAD.EQ.1)
     1WRITE(6,903)  (I,SUM11(I),SUM12(I),SUM22(I),SUM21(I),SUMS(I),I=1,
     2              MATYPE)
  903 FORMAT( /13X,10HENERGY-LLT,8X,10HENERGY-LLC,8X,10HENERGY-TTT,
     1       8X,10HENERGY-TTC,8X,9HENERGY-LT /
     2       (4H MAT ,I2,5E18.8,/ ))
C     WRITE(6,351)     (SUM1(I),SUM2(I),SUMS(I),I=1,LAMINA)
  351 FORMAT( /13X,9HENERGY-LL,9X,9HENERGY-TT,9X,9HENERGY-LT,/(
     1       7X,3E18.8))
```

SUBROUTINE OUTPUT

```
C     WRITE(6,352) (I,(ENER(I,J),J=1,3),I=1,LAMINA)
  352 FORMAT(2X,5HLAYER,8X,7HENER-LL,11X,7HENER-TT,11X,7HENER-LT/
     1        (3X,I2,3E18.8))
      WRITE(6,902)  (I,XL(I),XT(I),XS(I),XX(I),I=1,LAMINA)
  902 FORMAT( /7H  LAYER,5X,14HENERGY RATIO-L,4X,14HENERGY RATIO-T,4X,
     1        14HENERGY RATIO-S,4X,18HTOTAL CONTRIBUTION ,/
     2        (3X,I2,2X,4E18.8))
      WRITE(6,910)  ENTLE
  910 FORMAT( /53X,27HTOTAL ENERGY OF ALL LAYERS    ,E15.8,/ /)
      WRITE(6,100) (I,E11(I),E22(I),GG(I),UNN(I),I=1,LAMINA)
  100 FORMAT(33H  MODULI AT THE END OF INCREMENT    /
     1        7H  LAYER,9X,3HE11,15X,3HE22,15X,3HG12,15X,3HU12,  /
     2        (3X,I2,2X,4E18.8))
      WRITE(6,101)
  101 FORMAT(//22X,5HLONG.,5X,5HTRAN.,5X,5HSHEAR,  / )
  800 CONTINUE
      GO TO (810,820,830) ,NOPSHN
  810 CONTINUE
      GX=0.
      GY=0.
      GXX=0.
      DO 89 I=1,LAMINA
      KK=NLONG(I)
      LL=NTRAN(I)
      MM=NSHEAR(I)
      IF(NPR.EQ.1.OR.LB.EQ.0) WRITE(6,99) NLONG(I),NTRAN(I),NSHEAR(I)
      IF(KK-I) 82,83,82
   83 HK=H(I+1)-H(I)
      GX =GX +HK*(SIGDR1(I,1)*S6(I)+SIGDR1(I,2)*S7(I)+2.*S8(I)*
     1            SIGDR1(I,3))
      GY =GY +HK*(SIGDR1(I,1)*S7(I)+SIGDR1(I,2)*S6(I)-2.*S8(I)*
     1            SIGDR1(I,3))
      GXX=GXX+HK*((SIGDR1(I,2)-SIGDR1(I,1))*S8(I)+SIGDR1(I,3)*(
     1            S6(I)-S7(I)))
      SIGDR1(I,1)=0.
      SIGDR1(I,2)=0.
      SIGDR1(I,3)=0.
      GO TO 89
   82 IF(LL-I) 189,85,189
   85 GO TO(86,87),NALTER(I)
```

SUBROUTINE OUTPUT

```
   86 HK=H(I+1)-H(I)
      GX=GX+HK*(SIGDR1(I,2)*S7(I)+2.*S8(I)*SIGDR1(I,3))
      GY=GY+HK*(SIGDR1(I,2)*S6(I)-2.*S8(I)*SIGDR1(I,3))
      GXX=GXX+HK*(SIGDR1(I,2)*S8(I)+SIGDR1(I,3)*(S6(I)-S7(I)))
      SIGDR1(I,2)=0.
      SIGDR1(I,3)=0.
      GO TO 89
   87 HK=H(I+1)-H(I)
      GX=GX+HK*SIGDR1(I,2)*S7(I)
      GY=GY+HK*SIGDR1(I,2)*S6(I)
      GXX=GXX+HK*SIGDR1(I,2)*S8(I)
      SIGDR1(I,2)=0.
  189 IF(MM-I) 89,190,89
  190 HK=H(I+1)-H(I)
      GX=GX+2.*S8(I)*SIGDR1(I,3)
      GY=GY-2.*S8(I)*SIGDR1(I,3)
      GXX=GXX+(S6(I)-S7(I))*SIGDR1(I,3)
      SIGDR1(I,3)=0.
   89 CONTINUE
      XYZ=ABS(GX)+ABS(GY)+ABS(GXX)
      IF(XYZ.GT.1.) NOFF=1
      IF(NOFF.EQ.0) GO TO 401
      AB1=A1(KL)
      AB2=A2(KL)
      AB3=A3(KL)
      SIGXX=SIGXX-A1(KL)
      SIGYY=SIGYY-A2(KL)
      SIGXY=SIGXY-A3(KL)
      LOAD=LOAD-1
      A1(KL)=GX
      A2(KL)=GY
      A3(KL)=GXX
      CALL UNLOAD(DA)
      NOFF=0
      A1(KL)=AB1
        A2(KL)=AB2
          A3(KL)=AB3
      IF(EFF1.GE.0.5.OR.EFF2.GE.0.5) DA=0.
      IF(EFF1.GE.0.5.OR.EFF2.GE.0.5) WRITE(6,451) EFF1,EFF2
  451 FORMAT(//10X,17HLOADING UNSTABLE ,18HEFFECTIVE STRAINS=,2E18.8)
```

SUBROUTINE OUTPUT

```
      IF(DA.LE.0.) GO TO 401
      GO TO 20
  401 CONTINUE
      IF(EDIFF.LE.0.) WRITE(6,450) EDIFF
  450 FORMAT(//10X,17HLOADING UNSTABLE    ,24HEFFECTIVE STRESS DIFF.=   ,
     1          E18.8)
      IF(NPR.NE.1.OR.LB.NE.0) RETURN
      IF(NOFF.EQ.0) WRITE(6,103) (I,E11(I),E22(I),GG(I),UNN(I),I=1,
     1         LAMINA)
  103 FORMAT(/ 41H  MODULI AFTER  THE OF CALL FOR *UNLOAD*        //
     1          7H  LAYER,9X,3HE11,15X,3HE22,15X,3HG12,15X,3HU12,  /
     2          (3X,I2,2X,4E18.8))
  820 CONTINUE
  830 CONTINUE
      RETURN
      END
```

SUBROUTINE UNLOAD

```
C
      SUBROUTINE UNLOAD(DA)
C
      CALL ELCON
      IF(DA.LE.0.) RETURN
      CALL ITER
      RETURN
      END
```

APPENDIX B

EXAMPLES OF OUTPUT

SAMPLE EXAMPLES (0/45/-45/90) AND (0/90) LAMINATES OF BORON-EPOXY

MATERIAL 1

STRAIN 0 DEG.(TEN)	STRESS 0 DEG.(TEN)	STRAIN 0 DEG.(COM)	STRESS 0 DEG.(COM)
0.	0.	0.	0.
.10000000E-02	.29900000E+05	.10000000E-02	.35100000E+05
.20000000E-02	.59800000E+05	.15000000E-02	.52200000E+05
.30000000E-02	.89700000E+05	.20000000E-02	.69300000E+05
.40000000E-02	.11960000E+06	.25000000E-02	.86400000E+05
.48000000E-02	.14250000E+06	.30000000E-02	.10340000E+06
.53250000E-02	.15750000E+06	.35000000E-02	.12040000E+06
.60000000E-02	.17500000E+06	.40000000E-02	.13720000E+06
.66000000E-02	.19050000E+06	.44000000E-02	.15120000E+06
.72000000E-02	.20600000E+06	.50000000E-02	.17040000E+06
0.	0.	.55000000E-02	.18700000E+06
0.	0.	.60000000E-02	.20360000E+06
0.	0.	.67000000E-02	.22800000E+06
0.	0.	.80000000E-02	.26990000E+06
0.	0.	.10000000E-01	.33350000E+06
0.	0.	.12000000E-01	.39780000E+06
0.	0.	.12900000E-01	.41200000E+06
0.	0.	.13800000E-01	.42620000E+06

STRAIN 90DEG.(TEN)	STRESS 90DEG.(TEN)	STRAIN 90DEG.(COM)	STRESS 90DEG.(COM)	SHEAR STRAIN	SHEAR STRESS
0.	0.	0.	0.	0.	0.
.50000000E-03	.13550000E+04	.10000000E-02	.31000000E+04	.20000000E-02	.17320000E+04
.10000000E-02	.27100000E+04	.15000000E-02	.46800000E+04	.40000000E-02	.32440000E+04
.15000000E-02	.39500000E+04	.20000000E-02	.62400000E+04	.60000000E-02	.43290000E+04
.20000000E-02	.51750000E+04	.25000000E-02	.77900000E+04	.80000000E-02	.52200000E+04
.25000000E-02	.62500000E+04	.30000000E-02	.93400000E+04	.10000000E-01	.60060000E+04
.30000000E-02	.73100000E+04	.35000000E-02	.10890000E+05	.12000000E-01	.66720000E+04
.35000000E-02	.82500000E+04	.40000000E-02	.12440000E+05	.14000000E-01	.72250000E+04
.40000000E-02	.91200000E+04	.44000000E-02	.13740000E+05	.16000000E-01	.76850000E+04
.44500000E-02	.97500000E+04	.50000000E-02	.15540000E+05	.18000000E-01	.80710000E+04
.49000000E-02	.10380000E+05	.55000000E-02	.17080000E+05	.20000000E-01	.84000000E+04
0.	0.	.60000000E-02	.18620000E+05	.22000000E-01	.86900000E+04
0.	0.	.67000000E-02	.20570000E+05	.24000000E-01	.89420000E+04
0.	0.	.80000000E-02	.24000000E+05	.26000000E-01	.91640000E+04
0.	0.	.10000000E-01	.28850000E+05	.28000000E-01	.93580000E+04
0.	0.	.12000000E-01	.32960000E+05	.30000000E-01	.95330000E+04
0.	0.	.12900000E-01	.34620000E+05	.32000000E-01	.96920000E+04
0.	0.	.14000000E-01	.36700000E+05	.34000000E-01	.98510000E+04
0.	0.	.16000000E-01	.39780000E+05	0.	0.
0.	0.	.18000000E-01	.42640000E+05	0.	0.
0.	0.	.19700000E-01	.44810000E+05	0.	0.
0.	0.	.21400000E-01	.46980000E+05	0.	0.

STRAIN 0 DEG.(TEN)	TEN. POSSONS RATIO	STRAIN 0 DEG.(COM)	COM. POSSONS RATIO
0.	.21000000E+00	0.	.22500000E+00
.10000000E-02	.21000000E+00	.10000000E-02	.22500000E+00
.20000000E-02	.21000000E+00	.15000000E-02	.22500000E+00
.30000000E-02	.21000000E+00	.20000000E-02	.22500000E+00
.40000000E-02	.21000000E+00	.25000000E-02	.22500000E+00
.47000000E-02	.21000000E+00	.30000000E-02	.22500000E+00
.53250000E-02	.20900000E+00	.35000000E-02	.22500000E+00
.60000000E-02	.20450000E+00	.40000000E-02	.22500000E+00
.62250000E-02	.19500000E+00	.44000000E-02	.22500000E+00
.66000000E-02	.19000000E+00	.50000000E-02	.22500000E+00
.72000000E-02	.19000000E+00	.55000000E-02	.22500000E+00
0.	0.	.60000000E-02	.22500000E+00
0.	0.	.67000000E-02	.22500000E+00
0.	0.	.80000000E-02	.22500000E+00
0.	0.	.10000000E-01	.22500000E+00
0.	0.	.12000000E-01	.22500000E+00
0.	0.	.12900000E-01	.22500000E+00
0.	0.	.13800000E-01	.22500000E+00

INITIAL MODULI OF ELASTICITY
E1T= .29900000E+08 E1C= .33700000E+08 E2T= .27100000E+07 E2C= .27100000E+07 G12= .86600000E+06

SAMPLE EXAMPLES (0/45/-45/90) AND (0/90) LAMINATES OF BORON-EPOXY

MATERIAL 2

STRAIN 0 DEG.(TEN)	STRESS 0 DEG.(TEN)	STRAIN 0 DEG.(COM)	STRESS 0 DEG.(COM)
0.	0.	0.	0.
.19230770E-02	.20000000E+05	.19230770E-02	.20000000E+05
.38461540E-02	.40000000E+05	.38461540E-02	.40000000E+05
.57692310E-02	.60000000E+05	.57692310E-02	.60000000E+05
.67307690E-02	.70000000E+05	.67307690E-02	.70000000E+05
.75000000E-02	.78000000E+05	.75000000E-02	.78000000E+05
.12000000E-01	.81000000E+05	.12000000E-01	.81000000E+05
.26000000E-01	.84000000E+05	.26000000E-01	.84000000E+05
.40000000E-01	.86000000E+05	.40000000E-01	.86000000E+05
.54000000E-01	.87000000E+05	.54000000E-01	.87000000E+05
.80000000E-01	.88000000E+05	.80000000E-01	.88000000E+05
.10000000E+00	.88500000E+05	.10000000E+00	.88500000E+05
.12000000E+00	.89000000E+05	.12000000E+00	.89000000E+05

STRAIN 90DEG.(TEN)	STRESS 90DEG.(TEN)	STRAIN 90DEG.(COM)	STRESS 90DEG.(COM)	SHEAR STRAIN	SHEAR STRESS
0.	0.	0.	0.	0.	0.
.19230770E-02	.20000000E+05	.19230770E-02	.20000000E+05	.28867520E-02	.11547000E+05
.38461540E-02	.40000000E+05	.38461540E-02	.40000000E+05	.57735030E-02	.23094000E+05
.57692310E-02	.60000000E+05	.57692310E-02	.60000000E+05	.86602540E-02	.34641000E+05
.67307690E-02	.70000000E+05	.67307690E-02	.70000000E+05	.10103630E-01	.40414500E+05
.75000000E-02	.78000000E+05	.75000000E-02	.78000000E+05	.11258330E-01	.45033300E+05
.12000000E-01	.81000000E+05	.12000000E-01	.81000000E+05	.18013329E-01	.46765400E+05
.26000000E-01	.84000000E+05	.26000000E-01	.84000000E+05	.39028879E-01	.48497400E+05
.40000000E-01	.86000000E+05	.40000000E-01	.86000000E+05	.60044428E-01	.49652100E+05
.54000000E-01	.87000000E+05	.54000000E-01	.87000000E+05	.81059978E-01	.50229000E+05
.80000000E-01	.88000000E+05	.80000000E-01	.88000000E+05	.12008886E+00	.50806800E+05
.10000000E+00	.88500000E+05	.10000000E+00	.88500000E+05	.15011107E+00	.51095500E+05
.12000000E+00	.89000000E+05	.12000000E+00	.89000000E+05	.18013329E+00	.51384200E+05

STRAIN 0 DEG.(TEN)	TEN. POSSONS RATIO	STRAIN 0 DEG.(COM)	COM. POSSONS RATIO
0.	.30000000E+00	0.	.30000000E+00
.19230770E-02	.30000000E+00	.19230770E-02	.30000000E+00
.38461540E-02	.30000000E+00	.38461540E-02	.30000000E+00
.57692310E-02	.30000000E+00	.57692310E-02	.30000000E+00
.67307690E-02	.30000000E+00	.67307690E-02	.30000000E+00
.75000000E-02	.30000000E+00	.75000000E-02	.30000000E+00
.12000000E-01	.30000000E+00	.12000000E-01	.30000000E+00
.26000000E-01	.30000000E+00	.26000000E-01	.30000000E+00
.40000000E-01	.30000000E+00	.40000000E-01	.30000000E+00
.54000000E-01	.30000000E+00	.54000000E-01	.30000000E+00
.80000000E-01	.30000000E+00	.80000000E-01	.30000000E+00
.10000000E+00	.30000000E+00	.10000000E+00	.30000000E+00
.12000000E+00	.30000000E+00	.12000000E+00	.30000000E+00

INITIAL MODULI OF ELASTICITY
E1T= .10400000E+08 E1C= .10400000E+08 E2T= .10400000E+08 E2C= .10400000E+08 G12= .40000000E+07

```
                                                   LAMINATE NO.  1
NO. OF BOUNDING SURFACES-    5
DISTANCE OF   1-BOUNDARY -    0.0000
DISTANCE OF   2-BOUNDARY -     .0052
DISTANCE OF   3-BOUNDARY -     .0104
DISTANCE OF   4-BOUNDARY -     .0156
DISTANCE OF   5-BOUNDARY -     .0208

LAMINA     ORIENTATION     MATERIAL
   1          0.000           1
   2         45.000           1
   3        -45.000           1
   4         90.000           1

LOAD COMBINATION ---------------    1
STRESS RESULTANT INCREMENT NXX--    .10000000E+03
STRESS RESULTANT INCREMENT NYY--   0.
STRESS RESULTANT INCREMENT NXY--   0.

LOAD COMBINATION ---------------    2
STRESS RESULTANT INCREMENT NXX--    .10000000E+03
STRESS RESULTANT INCREMENT NYY--    .10000000E+03
STRESS RESULTANT INCREMENT NXY--   0.
```

```
LOAD INCREMENT    1     LOAD COMBINATION   1     LAMINATE NO. 1     NOPSHN NO.  1
EX=  .11680661E+08   EY=  .13019960E+08   UXY=  .28648981E+00   GXY=  .43883820E+07
ETA1=  .28571242E-11   ETA2= -.96623602E-11
ST. INCR.   DELEP(1)          DELEP(2)          DELEP(3)
           .41159420E-03    -.11791754E-03     .11759758E-14

                                           STRAINS - STRESS RESULTANTS / STRESSES
             STRAIN-XX         STRAIN-YY         STRAIN-XY        RESUL.-XX        RESUL.-YY        RESUL.-XY
           .41159420E-03    -.11791754E-03     .11759758E-14    .10000000E+03    0.               0.
                                                                .48076923E+04    0.               0.
LAYER        STRAIN-LL         STRAIN-TT         STRAIN-LT        STRESS-LL        STRESS-TT        STRESS-LT
  1        .41159420E-03    -.11791754E-03     .11759758E-14    .12283205E+05   -.97274658E+02    0.
  2        .14683833E-03     .14683833E-03     .52951174E-03    .44901721E+04    .48059144E+03    .46648714E+03
  3        .14683833E-03     .14683833E-03    -.52951174E-03    .44901721E+04    .48059144E+03   -.46648714E+03
  4       -.11791754E-03     .41159420E-03    -.65730841E-14   -.39405146E+04    .10438267E+04    0.
         STRESSES IN LAMINAE OBTAINED FROM STRESS-STRAIN CURVES
LAYER        STRAIN-L          STRAIN-T          STRAIN-LT        STRESS-L         STRESS-T         STRESS-LT
  1        .41091093E-03    -.31625653E-04     .11759758E-14    .12283370E+05   -.97282900E+02    0.
  2        .15021467E-03     .17338349E-03     .52951174E-03    .44901433E+04    .48068740E+03    .46634350E+03
  3        .15021467E-03     .17838349E-03    -.52951174E-03    .44901433E+04    .48068740E+03   -.46634350E+03
  4       -.11128479E-03     .38655511E-03    -.65730841E-14   .39404798E+04    .10448409E+04    0.
             ENERGY-LLT        ENERGY-LLC        ENERGY-TTT       ENERGY-TTC       ENERGY-LT
MAT 1      .64483175E+03     .27957636E+04     .24052808E+02    .51666040E+03    .21850173E+03
MAT 2      .82257247E+04     .82257247E+04     .82257247E+04    .82257247E+04    .21850173E+03

LAYER      ENERGY RATIO-L    ENERGY RATIO-T    ENERGY RATIO-S   TOTAL CONTRIBUTION
  1        .39266397E-02     .41390728E-04    0.                .39680304E-02
  2        .49974949E-03     .12071370E-02     .56541447E-03    .22723010E-02
  3        .49974949E-03     .12071370E-02     .56541447E-03    .22723010E-02
  4        .88054659E-04     .95027880E-02    0.                .95908427E-02
                                        TOTAL ENERGY OF ALL LAYERS    .18103475E-01

MODULI AT THE END OF INCREMENT
LAYER        E11               E22               G12              U12
  1        .29895835E+08     .30758695E+07     .88180701E+06    .21000260E+00
  2        .29892131E+08     .26991665E+07     .87848296E+06    .21000112E+00
  3        .29892131E+08     .26991665E+07     .87848296E+06    .21000112E+00
  4        .35400585E+08     .27238996E+07     .88180701E+06    .22500017E+00

                 LONG.         TRAN.         SHEAR
```

```
LOAD INCREMENT    12      LOAD COMBINATION   1      LAMINATE NO. 1      NOPSHN NO.  1
EX=  .10650562E+08   EY=  .12288350E+08   UXY=  .30373102E+00   GXY=  .43657981E+07
ETA1=  .27430199E-11   ETA2= -.92279364E-11
ST. INCR.  DELEP(1)        DELEP(2)         DELEP(3)
          .28212667E-04   -.85690621E-05    .77387908E-16

                                        STRAINS - STRESS RESULTANTS / STRESSES
          STRAIN-XX        STRAIN-YY        STRAIN-XY        RESUL.-XX         RESUL.-YY         RESUL.-XY
          .44499220E-02   -.13044604E-02    .12460488E-13    .10562500E+04    0.                0.

                                                             .50781250E+05    0.                0.
LAYER     STRAIN-LL        STRAIN-TT        STRAIN-LT        STRESS-LL         STRESS-TT         STRESS-LT
  1       .44499220E-02   -.13044604E-02    .12460488E-13    .13228026E+06   -.11444018E+04    0.
  2       .15727308E-02    .15727308E-02    .57543824E-02    .48077480E+05    .49658128E+04    .42119346E+04
  3       .15727308E-02    .15727308E-02   -.57543824E-02    .48077480E+05    .49658128E+04   -.42119346E+04
  4      -.13044604E-02    .44499220E-02   -.71112682E-13   -.43475022E+05    .93775769E+04    0.
        STRESSES IN LAMINAE OBTAINED FROM STRESS-STRAIN CURVES
LAYER     STRAIN-L         STRAIN-T         STRAIN-LT        STRESS-L          STRESS-T          STRESS-LT
  1       .44418457E-02   -.37166377E-03    .12460488E-13    .13226427E+06   -.11444055E+04    0.
  2       .16076007E-02    .19103257E-02    .57543824E-02    .48077492E+05    .49647035E+04    .42113617E+04
  3       .16076007E-02    .19103257E-02   -.57543824E-02    .48077492E+05    .49647035E+04   -.42113617E+04
  4      -.12442028E-02    .41599761E-02   -.71112682E-13   -.43474531E+05    .93697756E+04    0.
LAYER     ENERGY RATIO-L   ENERGY RATIO-T   ENERGY RATIO-S   TOTAL CONTRIBUTION
  1       .45901813E+00    .50984548E-02   0.                .46411658E+00
  2       .57347778E-01    .13796199E+00    .61179765E-01    .25648953E+00
  3       .57347778E-01    .13796199E+00    .61179765E-01    .25648953E+00
  4       .10696659E-01    .99996839E+00   0.                .10106650E+01
                                          TOTAL ENERGY OF ALL LAYERS   .19877607E+01

MODULI AT THE END OF INCREMENT
LAYER     E11              E22              G12              U12
  1       .28448783E+08    .30858267E+07    .88180701E+06    .21028835E+00
  2       .29900911E+08    .23864126E+07    .48396801E+06    .20999086E+00
  3       .29900911E+08    .23864126E+07    .48396801E+06    .20999086E+00
  4       .34156072E+08   0.               0.               0.

                    LONG.     TRAN.     SHEAR

LAYER FAILING         0         0         0
LAYER FAILING         0         0         0
LAYER FAILING         0         0         0
LAYER FAILING         0         4         4
ELCON CALLED FROM *UNLOAD*
                          MODULI OF ELASTICITY
              .28448783E+08    .30858267E+07     .88180701E+06     .21028835E+00
              .29900911E+08    .23864126E+07     .48396801E+06     .20999086E+00
              .29900911E+08    .23864126E+07     .48396801E+06     .20999086E+00
              .34156072E+08   0.                0.                0.
                          STRESS RESULTANTS
              .48763400E+02    .12664996E-20    -.24851323E-09
ELCON CALLED FROM *UNLOAD*
                          MODULI OF ELASTICITY
              .28486374E+08    .30863759E+07     .88180701E+06     .21023383E+00
              .29896515E+08    .23428810E+07     .47791312E+06     .20999090E+00
              .29896515E+08    .23428810E+07     .47791312E+06     .20999090E+00
              .34156072E+08   0.                0.                0.
                          STRESS RESULTANTS
              .48763400E+02    .12664996E-20    -.24851323E-09
```

```
LOAD INCREMENT    12        .AD COMBINATION   1      LAMINATE NO. 1      NOPSHN NO.  1

EX=  .10342132E+08    EY=     272840E+08    UXY=  .29819101E+00    GXY=  .41409282E+07

ETA1=  .72361663E-11     ..2= -.10414787E-10

ST. INCR.          (1)             DELEP(2)            DELEP(3)
            ......38...03     -.67595087E-04      -.21516968E-14

                                         STRAINS - STRESS RESULTANTS / STRESSES
           STRAIN-XX          STRAIN-YY           STRAIN-XY          RESUL.-XX              RESUL.-YY           RESUL.-XY
          .46766059E-02     -.13720555E-02       .10308791E-13      .10562500E+04      0.                  0.

                                                                    .50781250E+05      0.                  0.

LAYER      STRAIN-LL          STRAIN-TT           STRAIN-LT          STRESS-LL          STRESS-TT           STRESS-LT
  1       .46766059E-02     -.13720555E-02       .10308791E-13      .13872466E+06     -.12062355E+04       0.
  2       .16522752E-02      .16522752E-02       .60486614E-02      .50503096E+05      .51920923E+04       .43525744E+04
  3       .16522752E-02      .16522752E-02      -.60486614E-02      .50503096E+05      .51920923E+04      -.43525744E+04
  4      -.13720555E-02      .46766059E-02      -.71960456E-13     -.45783804E+05      0.                  0.

     STRESSES IN LAMINAE OBTAINED FROM STRESS-STRAIN CURVES
LAYER      STRAIN-L           STRAIN-T            STRAIN-LT          STRESS-L           STRESS-T            STRESS-LT
  1       .46680732E-02     -.39169818E-03       .10308791E-13      .13871150E+06     -.12063796E+04       0.
  2       .16887345E-02      .20069074E-02       .60486614E-02      .50503370E+05      .51908349E+04       .43520709E+04
  3       .16887345E-02      .20069074E-02      -.60486614E-02      .50503370E+05      .51908349E+04      -.43520709E+04
  4      -.13117979E-02      .43966599E-02      -.71960456E-13     -.43474531E+05      .93697756E+04       0.

LAYER      ENERGY RATIO-L     ENERGY RATIO-T      ENERGY RATIO-S     TOTAL CONTRIBUTION
  1       .50672960E+00      .56439466E-02       0.                 .51237355E+00
  2       .63296530E-01      .15195198E+00       .66946742E-01      .28219525E+00
  3       .63296530E-01      .15195198E+00       .66946742E-01      .28219525E+00
  4       .11825376E-01      .99996839E+00       0.                 .10117938E+01
                                                  TOTAL ENERGY OF ALL LAYERS    .20885578E+01

MODULI AT THE END OF INCREMENT
LAYER        E11                E22                G12                U12
  1       .28605298E+08      .30869397E+07       .88180701E+06      .21007001E+00
  2       .29891703E+08      .22925321E+07       .47297320E+06      .20999112E+00
  3       .29891703E+08      .22925321E+07       .47297320E+06      .20999112E+00
  4       .34156072E+08      0.                  0.                 0.

                          LONG.      TRAN.     SHEAR

LAYER FAILING               0          0         0
LAYER FAILING               0          0         0
LAYER FAILING               0          0         0
LAYER FAILING               0          4         4

MODULI AFTER  THE OF CALL FOR *UNLOAD*

LAYER        E11                E22                G12                U12
  1       .28605298E+08      .30869397E+07       .88180701E+06      .21007001E+00
  2       .29891703E+08      .22925321E+07       .47297320E+06      .20999112E+00
  3       .29891703E+08      .22925321E+07       .47297320E+06      .20999112E+00
  4       .34156072E+08      0.                  0.                 0.
```

```
        LOAD INCREMENT    18       LOAD COMBINATION   1      LAMINATE NO. 1      NDPSHN NO.  1
        EX=  .96302587E+07   EY=  .12117757E+08   UXY=  .29792214E+00   GXY=  .41159602E+07
        ETA1=  .31736106E-11   ETA2= -.10555174E-10
ST. INCR.   DELEP(1)          DELEP(2)          DELEP(3)
           .62403468E-04    -.18591375E-04     .19804430E-15

                                           STRAINS - STRESS RESULTANTS / STRESSES
           STRAIN-XX         STRAIN-YY          STRAIN-XY         RESUL.-XX            RESUL.-YY            RESUL.-XY
           .65640053E-02    -.19336946E-02     .16293247E-13     .14437500E+04     0.                   0.

                                                                 .69411058E+05     0.                   0.

LAYER      STRAIN-LL         STRAIN-TT          STRAIN-LT         STRESS-LL         STRESS-TT            STRESS-LT
  1        .65640053E-02    -.19336946E-02     .16293247E-13     .18922470E+06    -.17479984E+04       0.
  2        .23151553E-02     .23151553E-02     .84976999E-02     .70649170E+05     .69181886E+04        .54260851E+04
  3        .23151553E-02     .23151553E-02    -.84976999E-02     .70649170E+05     .69181886E+04       -.54260851E+04
  4       -.19336946E-02     .65640053E-02    -.10290701E-12    -.64967190E+05    0.                   0.
        STRESSES IN LAMINAE OBTAINED FROM STRESS-STRAIN CURVES
LAYER      STRAIN-L          STRAIN-T           STRAIN-LT         STRESS-L          STRESS-T             STRESS-LT
  1        .65513225E-02    -.56687557E-03     .16293247E-13     .18923782E+06    -.17480265E+04       0.
  2        .23637602E-02     .28115455E-02     .84976999E-02     .70649424E+05     .69185051E+04        .54256971E+04
  3        .23637602E-02     .28115455E-02    -.84976999E-02     .70649424E+05     .69185051E+04       -.54256971E+04
  4       -.18734370E-02     .62840593E-02    -.10290701E-12    -.43474531E+05     .93697756E+04       0.
LAYER      ENERGY RATIO-L    ENERGY RATIO-T     ENERGY RATIO-S    TOTAL CONTRIBUTION
  1        .98939228E+00     .11251011E-01     0.                .10006433E+01
  2        .12426775E+00     .29310837E+00     .12189196E+00     .53926809E+00
  3        .12426775E+00     .29310837E+00     .12189196E+00     .53926809E+00
  4        .23361398E-01     .99996939E+00     0.                .10233298E+01
                                                  TOTAL ENERGY OF ALL LAYERS   .31025093E+01

MODULI AT THE END OF INCREMENT
LAYER         E11               E22               G12               U12
  1        0.                0.                0.                0.
  2        .29830893E+08     .21273225E+07     .40709176E+06     .21002451E+00
  3        .29830893E+08     .21273225E+07     .40709176E+06     .21002451E+00
  4        .34156072E+08     0.                0.                0.

                     LONG.     TRAN.     SHEAR

LAYER FAILING          1         1         1
LAYER FAILING          0         0         0
LAYER FAILING          0         3         0
LAYER FAILING          0         4         4
ELCON CALLED FROM *UNLCAO*
                                 MODULI OF ELASTICITY
                 0.                0.                0.                0.
                 .29830893E+08     .21273225E+07     .40709176E+06     .21002451E+00
                 .29830893E+08     .21273225E+07     .40709176E+06     .21002451E+00
                 .34156072E+08     0.                0.                0.
                                 STRESS RESULTANTS
        REDUCE   .98396845E+03    -.93895916E+01     0.


   *** UNLOADING LEADS TO FAILURE OF LAMINATE ***           PROGRAM TERMINATED

MODULI AFTER  THE OF CALL FOR *UNLOAD*

LAYER         E11               E22               G12               U12
  1        0.                0.                0.                0.
  2        .29830893E+08     .21273225E+07     .40709176E+06     .21002451E+00
  3        .29830893E+08     .21273225E+07     .40709176E+06     .21002451E+00
  4        .34156072E+08     0.                0.                0.
```

LOAD INCREMENT 1 LOAD COMBINATION 2 LAMINATE NO. 1 NOPSHN NO. 1

EX= .11561033E+08 EY= .11561033E+08 UXY= .31710922E+00 GXY= .43887904E+07

ETA1= .26574733E-11 ETA2= -.80699692E-11

ST. INCR.	DELEP(1)	DELEP(2)	DELEP(3)
	.28398231E-03	.28398231E-03	-.22508037E-14

STRAINS - STRESS RESULTANTS / STRESSES

STRAIN-XX	STRAIN-YY	STRAIN-XY	RESUL.-XX	RESUL.-YY	RESUL.-XY
.28398231E-03	.28398231E-03	-.22508037E-14	.10000000E+03	.10000000E+03	0.
			.48076923E+04	.48076923E+04	0.

LAYER	STRAIN-LL	STRAIN-TT	STRAIN-LT	STRESS-LL	STRESS-TT	STRESS-LT
1	.28398231E-03	.28398231E-03	-.22508037E-14	.86843451E+04	.93103950E+03	0.
2	.28398231E-03	.28398231E-03	.22464669E-14	.86843451E+04	.93103950E+03	0.
3	.28398231E-03	.28398231E-03	-.22447322E-14	.86843451E+04	.93103950E+03	0.
4	.28398231E-03	.28398231E-03	.22508037E-14	.86843451E+04	.93103950E+03	0.

STRESSES IN LAMINAE OBTAINED FROM STRESS-STRAIN CURVES

LAYER	STRAIN-L	STRAIN-T	STRAIN-LT	STRESS-L	STRESS-T	STRESS-LT
1	.29052315E-03	.34499249E-03	-.22508037E-14	.86788743E+04	.93115109E+03	0.
2	.29052315E-03	.34499249E-03	.22464669E-14	.86788743E+04	.93115109E+03	0.
3	.29052315E-03	.34499249E-03	-.22447322E-14	.86788743E+04	.93115109E+03	0.
4	.29052315E-03	.34499249E-03	.22508037E-14	.86788743E+04	.93115109E+03	0.

	ENERGY-LLT	ENERGY-LLC	ENERGY-TTT	ENERGY-TTC	ENERGY-LT
MAT 1	.64483175E+03	.27957636E+04	.24052808E+02	.51666040E+03	.21850173E+03
MAT 2	.82257247E+04	.82257247E+04	.82257247E+04	.82257247E+04	.21850173E+03

LAYER	ENERGY RATIO-L	ENERGY RATIO-T	ENERGY RATIO-S	TOTAL CONTRIBUTION
1	.18692169E-02	.45184981E-02	0.	.63877150E-02
2	.18692169E-02	.45184981E-02	0.	.63877150E-02
3	.18692169E-02	.45184981E-02	0.	.63877150E-02
4	.18692169E-02	.45184981E-02	0.	.63877150E-02

TOTAL ENERGY OF ALL LAYERS .25550860E-01

MODULI AT THE END OF INCREMENT

LAYER	E11	E22	G12	U12
1	.29893694E+08	.27174725E+07	.88180701E+06	.21000202E+00
2	.29893694E+08	.27174725E+07	.88180701E+06	.21000202E+00
3	.29893694E+08	.27174725E+07	.88180701E+06	.21000202E+00
4	.29893694E+08	.27174725E+07	.88180701E+06	.21000202E+00
	LONG.	TRAN.	SHEAR	

```
LOAD INCREMENT    14      LOAD COMBINATION   2      LAMINATE NO. 1      NOPSHN NO.  1

EX=  .11095611E+08   EY=  .11095611E+08   UXY=  .30064843E+00   GXY=  .42654150E+07

ETA1=  .17782843E-11   ETA2= -.87346325E-11

ST. INCR.   DELEP(1)          DELEP(2)          DELEP(3)
          .37878347E-04     .37878347E-04    -.37677040E-15

                                          STRAINS - STRESS RESULTANTS / STRESSES
            STRAIN-XX         STRAIN-YY         STRAIN-XY         RESUL.-XX         RESUL.-YY         RESUL.-XY
          .36609963E-02     .36609963E-02    -.30479597E-13     .12625000E+04     .12625000E+04     0.

                                                                .60697115E+05     .60697115E+05     0.

LAYER       STRAIN-LL         STRAIN-TT         STRAIN-LT         STRESS-LL         STRESS-TT         STRESS-LT
  1       .36609963E-02     .36609963E-02    -.30479597E-13     .11164488E+06     .97493469E+04     0.
  2       .36609963E-02     .36609963E-02     .30460660E-13     .11164488E+06     .97493469E+04     0.
  3       .36609963E-02     .36609963E-02    -.30438759E-13     .11164488E+06     .97493469E+04     0.
  4       .36609963E-02     .36609963E-02     .30479597E-13     .11164488E+06     .97493469E+04     0.
        STRESSES IN LAMINAE OBTAINED FROM STRESS-STRAIN CURVES
LAYER       STRAIN-L          STRAIN-T          STRAIN-LT         STRESS-L          STRESS-T          STRESS-LT
  1       .37294076E-02     .44441305E-02    -.30479597E-13     .11163992E+06     .97420821E+04     0.
  2       .37294076E-02     .44441305E-02     .30460660E-13     .11163992E+06     .97420821E+04     0.
  3       .37294076E-02     .44441305E-02    -.30438759E-13     .11163992E+06     .97420821E+04     0.
  4       .37294076E-02     .44441305E-02     .30479597E-13     .11163992E+06     .97420821E+04     0.

LAYER     ENERGY RATIO-L    ENERGY RATIO-T    ENERGY RATIO-S    TOTAL CONTRIBUTION
  1       .31079452E+00     .69877251E+00     0.                .10095670E+01
  2       .31079452E+00     .69877251E+00     0.                .10095670E+01
  3       .31079452E+00     .69877251E+00     0.                .10095670E+01
  4       .31079452E+00     .69877251E+00     0.                .10095670E+01
                                          TOTAL ENERGY OF ALL LAYERS   .40382681E+01

MODULI AT THE END OF INCREMENT
LAYER          E11               E22               G12               U12
  1       0.                0.                0.                0.
  2       0.                0.                0.                0.
  3       0.                0.                0.                0.
  4       0.                0.                0.                0.

                         LONG.     TRAN.     SHEAR

LAYER FAILING              1         1         1
LAYER FAILING              2         2         2
LAYER FAILING              3         3         3
LAYER FAILING              4         4         4
ELCON CALLED FROM *UNLOAD*
                                   MODULI OF ELASTICITY
               0.                  0.                  0.                  0.
               0.                  0.                  0.                  0.
               0.                  0.                  0.                  0.
               0.                  0.                  0.                  0.
                                   STRESS RESULTANTS
             .12625000E+04         .12625000E+04       .28105673E-09

EX=  .11095611E+08   EY=  .11095611E+08   UXY=  .30064843E+00   GXY=  .42654150E+07

ETA1=  .17782843E-11   ETA2= -.87346325E-11

 MATRIX *A* IS SINGULAR
```

```
                                                 LAMINATE NO.  2
NO. OF BOUNDING SURFACES-    3
DISTANCE OF   1-BOUNDARY -    -.0052
DISTANCE OF   2-BOUNDARY -    0.0000
DISTANCE OF   3-BOUNDARY -     .0052

LAMINA     ORIENTATION     MATERIAL
  1           0.000           1
  2          90.000           1

LOAD COMBINATION ---------------    1
STRESS RESULTANT INCREMENT NXX--    .50000000E+02
STRESS RESULTANT INCREMENT NYY--   0.
STRESS RESULTANT INCREMENT NXY--   0.
```

```
         LOAD INCREMENT     1       LOAD COMBINATION   1       LAMINATE NO. 2      NOPSHN NO.  1
         EX=  .16341277E+08   EY=  .19105132E+08   UXY=  .30765999E-01   GXY=  .88180701E+06
         ETA1=  .39165544E-11   ETA2= -.95904621E-10

   ST. INCR.   DELEP(1)          DELEP(2)          DELEP(3)
             .29420543E-03    -.90515238E-05     .11522716E-14

                                              STRAINS - STRESS RESULTANTS / STRESSES
              STRAIN-XX         STRAIN-YY         STRAIN-XY         RESUL.-XX         RESUL.-YY          RESUL.-XY
             .29420543E-03    -.90515238E-05     .11522716E-14     .50000003E+02     0.                0.

                                                                   .48076923E+04     0.                0.

   LAYER      STRAIN-LL         STRAIN-TT         STRAIN-LT         STRESS-LL         STRESS-TT          STRESS-LT
     1       .29420543E-03    -.90515238E-05     .11522716E-14     .88243575E+04     .14255307E+03     0.
     2      -.90515238E-05     .29420543E-03    -.42432523E-14    -.14255307E+03     .79102711E+03     0.
         STRESSES IN LAMINAE OBTAINED FROM STRESS-STRAIN CURVES
   LAYER      STRAIN-L          STRAIN-T          STRAIN-LT         STRESS-L          STRESS-T           STRESS-LT
     1       .29520690E-03     .52942251E-04     .11522716E-14     .88189302E+04     .13896313E+03     0.
     2      -.40255351E-05     .29329968E-03    -.42432523E-14    -.16591043E+03     .79106305E+03     0.
              ENERGY-LLT        ENERGY-LLC        ENERGY-TTT        ENERGY-TTC        ENERGY-LT
  MAT 1      .64483175E+03     .27957636E+04     .24352808E+02     .51666040E+03     .21850173E+03

  MAT 2      .82257247E+04     .82257247E+04     .82257247E+04     .82257247E+04     .21850173E+03

   LAYER      ENERGY RATIO-L    ENERGY RATIO-T    ENERGY RATIO-S    TOTAL CONTRIBUTION
     1       .20062213E-02     .45956370E-05     0.                .20108069E-02
     2       .51887830E-06     .48500505E-02     0.                .48505694E-02
                                                       TOTAL ENERGY OF ALL LAYERS    .68613763E-02

   MODULI AT THE END OF INCREMENT
   LAYER       E11               E22               G12               U12
     1       .29893764E+08     .26930346E+07     .88180701E+06     .21000205E+00
     2       .35412163E+08     .27105475E+07     .88180701E+06     .22500001E+00

                        LONG.      TRAN.      SHEAR
```

```
      LOAD INCREMENT    18      LOAD COMBINATION   1      LAMINATE NO. 2      NOPSHN NO.  1

      EX=  .14951656E+08   EY=  .19085499E+08   UXY=  .22947252E-01   GXY=  .88180701E+06

      ETA1=  .15099645E-12   ETA2= -.96480885E-10

ST. INCR.  DELEP(1)          DELEP(2)          DELEP(3)
          .50242055E-05    -.11529171E-06     .75863721E-18

                                             STRAINS - STRESS RESULTANTS / STRESSES
            STRAIN-XX          STRAIN-YY          STRAIN-XY          RESUL.-XX           RESUL.-YY            RESUL.-XY
          .44467457E-02     -.12430865E-03     .11208820E-13      .74140625E+03    0.                     0.

                                                                  .71289063E+05    0.                     0.

LAYER       STRAIN-LL          STRAIN-TT          STRAIN-LT          STRESS-LL          STRESS-TT            STRESS-LT
  1       .44467457E-02     -.12430865E-03     .11208820E-13      .13285094E+06     .22132865E+04    0.
  2      -.12430865E-03      .44467457E-02    -.57799808E-13     -.22132865E+04     .97271829E+04    0.
      STRESSES IN LAMINAE OBTAINED FROM STRESS-STRAIN CURVES
LAYER       STRAIN-L           STRAIN-T           STRAIN-LT          STRESS-L           STRESS-T             STRESS-LT
  1       .44623630E-02      .81280639E-03     .11208820E-13      .13284771E+06     .22132299E+04    0.
  2      -.62502858E-04      .44326826E-02    -.57799808E-13     -.22132862E+04     .97265520E+04    0.

LAYER     ENERGY RATIO-L     ENERGY RATIO-T     ENERGY RATIO-S     TOTAL CONTRIBUTION
  1       .45836571E+00      .86505927E-03     0.                 .45923077E+00
  2       .97857786E-04      .99868115E+00     0.                 .99877900E+00
                                                 TOTAL ENERGY OF ALL LAYERS    .14580098E+01

MODULI AT THE END OF INCREMENT
LAYER       E11               E22                G12                U12
  1       .28449563E+08     .27079462E+07      .88180701E+06      .21028527E+00
  2       .35408525E+08    0.                 0.                 0.

                  LONG.      TRAN.      SHEAR

LAYER FAILING       0          0          0
LAYER FAILING       0          2          2
ELCON CALLED FROM *UNLOAD*
                          MODULI OF ELASTICITY
          .28449563E+08          .27079462E+07          .88180701E+06          .21028527E+00
          .35408525E+08       0.                     0.                     0.
                          STRESS RESULTANTS
          .50581351E+02          .13137161E-20         -.25777807E-09
ELCON CALLED FROM *UNLOAD*
                          MODULI OF ELASTICITY
          .28560101E+08          .26906281E+07          .88180701E+06          .21013372E+00
          .35408525E+08       0.                     0.                     0.
                          STRESS RESULTANTS
          .50581351E+02          .13137161E-20         -.25777807E-09
ELCON CALLED FROM *UNLOAD*
                          MODULI OF ELASTICITY
          .28559315E+08          .26919070E+07          .88180701E+06          .21013481E+00
          .35408525E+08       0.                     0.                     0.
                          STRESS RESULTANTS
          .50581351E+02          .13137161E-20         -.25777807E-09
```

```
LOAD INCREMENT    18      LOAD COMBINATION   1      LAMINATE NO. 2      NOPSHN NO.  1
EX=  .14335106E+08   EY=  .19050216E+08   UXY=  .14904289E-01   GXY=  .44090351E+06
ETA1=  .30500087E-11   ETA2= -.20463967E-09
ST. INCR.   DELEP(1)          CELEP(2)           DELEP(3)
           .33927839E-03    -.50567030E-05     -.55182380E-13

                                          STRAINS - STRESS RESULTANTS / STRESSES
           STRAIN-XX         STRAIN-YY          STRAIN-XY          RESUL.-XX          RESUL.-YY          RESUL.-XY
           .47860241E-02    -.12936535E-03     -.43973560E-13      .74140625E+03     0.                 0.
                                                                   .71289063E+05     0.                 0.
LAYER      STRAIN-LL         STRAIN-TT          STRAIN-LT          STRESS-LL          STRESS-TT          STRESS-LT
  1        .47860241E-02    -.12936535E-03     -.43973560E-13      .14257813E+06     .23923369E+04      0.
  2       -.12936535E-03     .47860241E-02     -.61271023E-14     -.23923369E+04     0.                 0.
           STRESSES IN LAMINAE OBTAINED FROM STRESS-STRAIN CURVES
LAYER      STRAIN-L          STRAIN-T           STRAIN-LT          STRESS-L           STRESS-T           STRESS-LT
  1        .48029589E-02     .87932072E-03     -.43973560E-13      .14258509E+06     .23921722E+04      0.
  2       -.67559561E-04     .47719610E-02     -.61271023E-14     -.22132862E+04     .97265520E+04      0.
LAYER      ENERGY RATIO-L    ENERGY RATIO-T     ENERGY RATIO-S     TOTAL CONTRIBUTION
  1        .53057450E+00     .93688519E-03     0.                  .53151138E+00
  2        .10598055E-03     .99868115E+00     0.                  .99878713E+00
                                                   TOTAL ENERGY OF ALL LAYERS    .15302985E+01

MODULI AT THE END OF INCREMENT
LAYER        E11               E22                G12                U12
  1        .28853300E+08     .267354339E+07     .88180701E+06      .20970730E+00
  2        .35408525E+08    0.                 0.                 0.

                        LONG.      TRAN.      SHEAR
LAYER FAILING             0          0          0
LAYER FAILING             0          2          2
MODULI AFTER  THE OF CALL FOR *UNLOAD*
LAYER        E11               E22                G12                U12
  1        .28853300E+08     .267354339E+07     .88180701E+06      .20970730E+00
  2        .35408525E+08    0.                 0.                 0.
```

```
LOAD INCREMENT    27       LOAD COMBINATION   1       LAMINATE NO. 2       NOPSHN NO.  1
EX=  .13008964E+08   EY=  .18935335E+08   UXY=  .12393778E-01   GXY=  .44090351E+06
ETA1=  .25362586E-11   ETA2= -.20463967E-09
ST. INCR.   DELEP(1)            DELEP(2)            DELEP(3)
          .11548989E-04     -.14313560E-06      .29291222E-16
                                          STRAINS - STRESS RESULTANTS / STRESSES
          STRAIN-XX           STRAIN-YY           STRAIN-XY          RESUL.-XX          RESUL.-YY          RESUL.-XY
          .65706278E-02     -.15401633E-03     -.38928993E-13      .98984375E+03    0.                 0.
                                                                   .95177284E+05    0.                 0.
LAYER     STRAIN-LL           STRAIN-TT           STRAIN-LT          STRESS-LL          STRESS-TT          STRESS-LT
  1       .65706278E-02     -.15401633E-03     -.38928993E-13      .19035457E+06     .32651916E+04    0.
  2      -.15401633E-03      .65706278E-02     -.29612703E-13     -.32651916E+04    0.                 0.
          STRESSES IN LAMINAE OBTAINED FROM STRESS-STRAIN CURVES
LAYER     STRAIN-L            STRAIN-T            STRAIN-LT          STRESS-L           STRESS-T           STRESS-LT
  1       .65942630E-02      .12207610E-02     -.38928993E-13      .19035126E+06     .32651170E+04    0.
  2      -.92210537E-04      .65565647E-02     -.29612703E-13     -.22132862E+04     .97265520E+04    0.
LAYER     ENERGY RATIO-L      ENERGY RATIO-T      ENERGY RATIO-S     TOTAL CONTRIBUTION
  1       .99134005E+00      .13280776E-02      0.                 .99266813E+00
  2       .15021399E-03      .99868115E+00      0.                 .99883136E+00
                                                  TOTAL ENERGY OF ALL LAYERS    .19914995E+01

MODULI AT THE END OF INCREMENT
LAYER          E11                 E22                 G12                 U12
  1       0.                  0.                  0.                  0.
  2        .35408525E+08      0.                  0.                   .22500010E+00

                    LONG.        TRAN.        SHEAR
LAYER FAILING         1            0            0
LAYER FAILING         0            2            2
ELCON CALLED FROM *UNLOAD*      MODULI OF ELASTICITY
               0.                  0.                  0.                  0.
                .35408525E+08      0.                  0.                   .22500010E+00
                            STRESS RESULTANTS
                .98984375E+03      .16978997E+02      0.
     EX=  .13008964E+08   EY=  .18935335E+08   UXY=  .12393778E-01   GXY=  .44090351E+06
     ETA1=  .25362586E-11   ETA2= -.20463967E-09
      MATRIX *A* IS SINGULAR
MODULI AFTER  THE OF CALL FOR *UNLOAD*
LAYER          E11                 E22                 G12                 U12
  1       0.                  0.                  0.                  0.
  2        .35408525E+08      0.                  0.                   .22500010E+00
```

```
                                                          LAMINATE NC.   3
NO. OF BOUNDING SURFACES-     6
CISTANCE OF   1-BOUNDARY -     -.1050
CISTANCE OF   2-BOUNDARY -     -.0575
DISTANCE OF   3-BOUNDARY -     -.0263
CISTANCE OF   4-BCUNDARY -     -.0158
DISTANCE OF   5-BOUNDARY -     -.0053
CISTANCE OF   6-BCUNDARY -     0.0000

LAMINA    ORIENTATION    MATERIAL
   1          0.000          2
   2          0.000          1
   3        -45.000          1
   4         45.000          1
   5         90.000          1

LOAD COMBINATION ---------------     1
STRESS RESULTANT INCREMENT NXX--     .40000000E+03
STRESS RESULTANT INCREMENT NYY--    0.
STRESS RESULTANT INCREMENT NXY--    0.
```

```
LOAD INCREMENT      1     LOAD COMBINATION   1      LAMINATE NO. 3      NOPSHN NO.  1
EX=  .15001257E+08   EY=  .90661721E+07   UXY=  .33799739E+00   GXY=  .36959545E+07
ETA1=  .79606761E-12   ETA2= -.22919376E-11

ST. INCR.   DELEP(1)           DELEP(2)          DELEP(3)
           .25394698E-03     -.85833414E-04     .20215896E-15

                                        STRAINS - STRESS RESULTANTS / STRESSES
             STRAIN-XX          STRAIN-YY          STRAIN-XY          RESUL.-XX          RESUL.-YY          RESUL.-XY
           .25394698E-03     -.85833414E-04     .20215896E-15     .40000000E+03     0.                 0.

                                                                  .38095238E+04     0.                 0.

LAYER        STRAIN-LL          STRAIN-TT          STRAIN-LT          STRESS-LL          STRESS-TT          STRESS-LT
  1        .25394698E-03     -.85833414E-04     .20215896E-15     .26093135E+04     -.11033579E+03     0.
  2        .25394698E-03     -.85833414E-04     .20215896E-15     .75698833E+04     -.10043303E+03     0.
  3        .84056781E-04      .84056781E-04    -.33978039E-03     .25703416E+04      .27499652E+03     -.29950447E+03
  4        .84056781E-04      .84056781E-04     .33978039E-03     .25703416E+04      .27499652E+03      .29950447E+03
  5       -.85833414E-04      .25394698E-03    -.36654090E-14    -.28965665E+04      .63487819E+03     0.

          STRESSES IN LAMINAE OBTAINED FROM STRESS-STRAIN CURVES
LAYER        STRAIN-L           STRAIN-T           STRAIN-LT          STRESS-L           STRESS-T           STRESS-LT
  1        .25076586E-03     -.10603657E-04     .20215896E-15     .26093074E+04     -.11033688E+03     0.
  2        .25324140E-03     -.32652479E-04     .20215896E-15     .75699175E+04     -.10043353E+03     0.
  3        .85988740E-04      .10211444E-03    -.33978039E-03     .25703411E+04      .27501502E+03     -.29946580E+03
  4        .85988740E-04      .10211444E-03     .33978039E-03     .25703411E+04      .27501502E+03      .29946580E+03
  5       -.81799380E-04      .23554211E-03    -.36654090E-14    -.28965230E+04      .63510737E+03     0.

             ENERGY-LLT         ENERGY-LLC         ENERGY-TTT         ENERGY-TTC         ENERGY-LT
MAT 1      .64483175E+03      .27957636E+04      .24052808E+02      .51666040E+03      .71289443E+04

MAT 2      .82257247E+04      .82257247E+04      .82257247E+04      .82257247E+04      .21850173E+03

LAYER      ENERGY RATIO-L     ENERGY RATIO-T     ENERGY RATIO-S     TOTAL CONTRIBUTION
  1        .40788779E-04      .46598200E-05     0.                 .45448599E-04
  2        .14947282E-02      .21930465E-04     0.                 .15166586E-02
  3        .16376388E-03      .39549524E-03      .23290184E-03     .79216096E-03
  4        .16376388E-03      .39549524E-03      .23290184E-03     .79216096E-03
  5        .46657443E-04      .36124875E-02     0.                 .36591449E-02
                                              TOTAL ENERGY OF ALL LAYERS     .68055741E-02

MODULI AT THE END OF INCREMENT
LAYER          E11                E22                G12                U12
  1        .10405170E+08      .10405447E+08      .40020924E+07      .30000000E+00
  2        .29893184E+08      .30758743E+07      .88180701E+06      .21000181E+00
  3        .29891747E+08      .26946674E+07      .88043832E+06      .21000065E+00
  4        .29891747E+08      .26946674E+07      .88043832E+06      .21000065E+00
  5        .35405917E+08      .27041423E+07      .88180701E+06      .22500013E+00

                 LONG.          TRAN.         SHEAR
```

```
        LOAD INCREMENT    19      LOAD COMBINATION   1      LAMINATE NO. 3      NOPSHN NO.  1
        EX=  .14379299E+08   EY=  .88597419E+07   UXY=  .34914995E+00   GXY=  .36900564E+07
        ETA1=  .73510429E-12   ETA2= -.21995807E-11
ST. INCR.   DELEP(1)          DELEP(2)          DELEP(3)
          .33116349E-04     -.11562586E-04     .24344000E-16

                                             STRAINS - STRESS RESULTANTS / STRESSES
          STRAIN-XX          STRAIN-YY          STRAIN-XY          RESUL.-XX                RESUL.-YY             RESUL.-XY
         .44462752E-02     -.15230730E-02      .34334882E-14      .69500000E+04       0.                      0.

                                                                  .66190476E+05       0.                      0.

LAYER     STRAIN-LL          STRAIN-TT          STRAIN-LT          STRESS-LL           STRESS-TT             STRESS-LT
  1      .44462752E-02     -.15230730E-02      .34334882E-14      .45618778E+05      -.21632603E+04         0.
  2      .44462752E-02     -.15230730E-02      .34334882E-14      .13202613E+06      -.18260381E+04         0.
  3      .14616011E-02      .14616011E-02     -.59693482E-02      .44684782E+05       .46364281E+04        -.43146574E+04
  4      .14616011E-02      .14616011E-02      .59693482E-02      .44684782E+05       .46364281E+04         .43146574E+04
  5     -.15230730E-02      .44462752E-02     -.64276745E-13     -.50942162E+05       .92973569E+04         0.
        STRESSES IN LAMINAE OBTAINED FROM STRESS-STRAIN CURVES
LAYER     STRAIN-L           STRAIN-T           STRAIN-LT          STRESS-L            STRESS-T              STRESS-LT
  1      .43839162E-02     -.20789817E-03      .34334882E-14      .45618755E+05      -.21632590E+04         0.
  2      .44333926E-02     -.59204819E-03      .34334882E-14      .13202365E+06      -.18260440E+04         0.
  3      .14941582E-02      .17753740E-02     -.59693482E-02      .44684799E+05       .46363150E+04        -.43144423E+04
  4      .14941582E-02      .17753740E-02      .59693482E-02      .44684799E+05       .46363150E+04         .43144423E+04
  5     -.14631251E-02      .41170719E-02     -.64276745E-13     -.50942317E+05       .92946767E+04         0.

LAYER    ENERGY RATIO-L     ENERGY RATIO-T     ENERGY RATIO-S     TOTAL CONTRIBUTION
  1      .12497260E-01      .14669886E-02      0.                 .13964248E-01
  2      .45826910E+00      .69635685E-02      0.                 .46523267E+00
  3      .49528254E-01      .11951464E+00      .65373827E-01      .23441672E+00
  4      .49528254E-01      .11951464E+00      .65373827E-01      .23441672E+00
  5      .14548445E-01      .99849050E+00      0.                 .10130389E+01
                                             TOTAL ENERGY OF ALL LAYERS    .19610693E+01


MODULI AT THE END OF INCREMENT
LAYER        E11                E22                G12                U12
  1      .10450415E+08      .10405257E+08      .40020924E+07      .30000000E+00
  2      .28449240E+08      .31012480E+07      .88180701E+06      .21028884E+00
  3      .29910990E+08      .24712032E+07      .47551815E+06      .20999149E+00
  4      .29910990E+08      .24712032E+07      .47551815E+06      .20999149E+00
  5      .34103981E+08     0.                 0.                 0.

                    LONG.      TRAN.      SHEAR

LAYER FAILING         0          0          0
LAYER FAILING         0          0          0
LAYER FAILING         0          0          0
LAYER FAILING         0          0          0
LAYER FAILING         0          5          5
ELCON CALLED FROM *UNLCAD*
                                  MODULI OF ELASTICITY
                   .10450415E+08          .10405257E+08          .40020924E+07          .30000000E+00
                   .28449240E+08          .31012480E+07          .88180701E+06          .21028884E+00
                   .29910990E+08          .24712032E+07          .47551815E+06          .20999149E+00
                   .29910990E+08          .24712032E+07          .47551815E+06          .20999149E+00
                   .34103981E+08         0.                     0.                     0.
                                  STRESS RESULTANTS
                   .48811123E+02          .12677391E-20         -.24875645E-09
ELCON CALLED FROM *UNLCAD*
                                  MODULI OF ELASTICITY
                   .10450037E+08          .10405255E+08          .40020924E+07          .30000000E+00
                   .28448763E+08          .31014409E+07          .88180701E+06          .21028751E+00
                   .29910583E+08          .24683960E+07          .47479883E+06          .20999144E+00
                   .29910583E+08          .24683960E+07          .47479883E+06          .20999144E+00
                   .34103981E+08         0.                     0.                     0.
                                  STRESS RESULTANTS
                   .48811123E+02          .12677391E-20         -.24875645E-09
```

LOAD INCREMENT 19 LOAD COMBINATION 1 LAMINATE NO. 3 NOPSHN NO. 1

EX= .14315702E+08 EY= .88591778E+07 UXY= .34758223E+00 GXY= .36457514E+07

ETA1= .83327826E-12 ETA2= -.23779272E-11

	DELEP(1)	DELEP(2)	DELEP(3)
ST. INCR.	.32472585E-04	-.11286894E-04	-.62276867E-15

STRAINS - STRESS RESULTANTS / STRESSES

STRAIN-XX	STRAIN-YY	STRAIN-XY	RESUL.-XX	RESUL.-YY	RESUL.-XY
.44787477E-02	-.15343599E-02	.28107195E-14	.69500000E+04	0.	0.
			.66190476E+05	0.	0.

LAYER	STRAIN-LL	STRAIN-TT	STRAIN-LT	STRESS-LL	STRESS-TT	STRESS-LT
1	.44787477E-02	-.15343599E-02	.28107195E-14	.45952819E+05	-.21809202E+04	0.
2	.44787477E-02	-.15343599E-02	.28107195E-14	.13294701E+06	-.18399323E+04	0.
3	.14721939E-02	.14721939E-02	-.60131077E-02	.45008289E+05	.46681817E+04	-.43354343E+04
4	.14721939E-02	.14721939E-02	.60131077E-02	.45008289E+05	.46681817E+04	.43354343E+04
5	-.15343599E-02	.44787477E-02	-.64099999E-13	-.51327090E+05	0.	0.

STRESSES IN LAMINAE OBTAINED FROM STRESS-STRAIN CURVES

LAYER	STRAIN-L	STRAIN-T	STRAIN-LT	STRESS-L	STRESS-T	STRESS-LT
1	.44158818E-02	-.20959538E-03	.28107195E-14	.45952740E+05	-.21809174E+04	0.
2	.44657625E-02	-.59652810E-03	.28107195E-14	.13294438E+06	-.18399357E+04	0.
3	.15049740E-02	.17882380E-02	-.60131077E-02	.45008263E+05	.46680631E+04	-.43352161E+04
4	.15049740E-02	.17882380E-02	.60131077E-02	.45008263E+05	.46680631E+04	.43352161E+04
5	-.14744120E-02	.41495444E-02	-.64099999E-13	-.50942317E+05	.92946767E+04	0.

LAYER	ENERGY RATIO-L	ENERGY RATIO-T	ENERGY RATIO-S	TOTAL CONTRIBUTION
1	.12680590E-01	.14888081E-02	0.	.14169398E-01
2	.46495929E+00	.70677800E-02	0.	.47202707E+00
3	.50248909E-01	.12121822E+00	.66239964E-01	.23770709E+00
4	.50248909E-01	.12121822E+00	.66239964E-01	.23770709E+00
5	.14763140E-01	.99849050E+00	0.	.10132536E+01

TOTAL ENERGY OF ALL LAYERS .19748643E+01

MODULI AT THE END OF INCREMENT

LAYER	E11	E22	G12	U12
1	.10449616E+08	.10405253E+08	.40020924E+07	.30000000E+00
2	.28449951E+08	.31016346E+07	.88180701E+06	.21028450E+00
3	.29910169E+08	.24654647E+07	.47410102E+06	.20999139E+00
4	.29910169E+08	.24654647E+07	.47410102E+06	.20999139E+00
5	.34103981E+08	0.	0.	0.

	LONG.	TRAN.	SHEAR
LAYER FAILING	0	0	0
LAYER FAILING	0	0	0
LAYER FAILING	0	0	0
LAYER FAILING	0	0	0
LAYER FAILING	0	5	5

```
LOAD INCREMENT    28      LOAD COMBINATION   1      LAMINATE NO. 3      NOPSHN NO.  1

EX=  .13560595E+08   EY=  .87988801E+07   UXY=  .34573579E+00   GXY=  .36313003E+07

ETA1=  .82499769E-12   ETA2= -.23959839E-11

ST. INCR.   DELEP(1)          DELEP(2)          DELEP(3)
           .35115750E-04    -.12140772E-04     .28970413E-16

                                           STRAINS - STRESS RESULTANTS / STRESSES
             STRAIN-XX         STRAIN-YY         STRAIN-XY         RESUL.-XX         RESUL.-YY         RESUL.-XY
           .65814646E-02    -.22633784E-02     .45661284E-14     .10000000E+05     0.                0.

                                                                 .95238095E+05     0.                0.

LAYER        STRAIN-LL         STRAIN-TT         STRAIN-LT         STRESS-LL         STRESS-TT         STRESS-LT
  1        .65814646E-02    -.22633784E-02     .45661284E-14     .67390560E+05    -.33043325E+04     0.
  2        .65814646E-02    -.22633784E-02     .45661284E-14     .18949341E+06    -.27703064E+04     0.
  3        .21590431E-02     .21590431E-02    -.88448430E-02     .65908001E+05     .65111444E+04    -.55656271E+04
  4        .21590431E-02     .21590431E-02     .88448430E-02     .65908001E+05     .65111444E+04     .55656271E+04
  5       -.22633784E-02     .65814646E-02    -.94718191E-13    -.76189522E+05     0.                0.

         STRESSES IN LAMINAE OBTAINED FROM STRESS-STRAIN CURVES
LAYER        STRAIN-L          STRAIN-T          STRAIN-LT         STRESS-L          STRESS-T          STRESS-LT
  1        .64860531E-02    -.31756247E-03     .45661284E-14     .67393026E+05    -.33043048E+04     0.
  2        .65613863E-02    -.89503984E-03     .45661284E-14     .18949807E+06    -.27703140E+04     0.
  3        .22047815E-02     .26220447E-02    -.88448430E-02     .65907841E+05     .65114243E+04    -.55654287E+04
  4        .22047815E-02     .26220447E-02     .88448430E-02     .65907841E+05     .65114243E+04     .55654287E+04
  5       -.22034334E-02     .62522613E-02    -.94718191E-13    -.50942317E+05     .92946767E+04     0.

LAYER        ENERGY RATIO-L    ENERGY RATIO-T    ENERGY RATIO-S    TOTAL CONTRIBUTION
  1        .27353416E-01     .32390220E-02     0.                .30622438E-01
  2        .99453107E+00     .15427850E-01     0.                .10099589E+01
  3        .10807826E+00     .25614087E+00     .13062342E+00     .49484255E+00
  4        .10807826E+00     .25614087E+00     .13062342E+00     .49484255E+00
  5        .31931468E-01     .99849050E+00     0.                .10304220E+01
                                                   TOTAL ENERGY OF ALL LAYERS    .33606884E+01

MODULI AT THE END OF INCREMENT
LAYER        E11               E22               G12               U12
  1        .10516125E+08     .10405002E+08     .40020924E+07     .30000000E+00
  2       0.                0.                0.                0.
  3        .29819612E+08     .21539483E+07     .39796301E+06     .21001350E+00
  4        .29819612E+08     .21539483E+07     .39796301E+06     .21001350E+00
  5        .34103981E+08    0.                0.                0.

                         LONG.      TRAN.      SHEAR

LAYER FAILING              0          0          0
LAYER FAILING              2          2          2
LAYER FAILING              0          0          0
LAYER FAILING              0          0          0
LAYER FAILING              0          5          5
ELCON CALLED FROM *UNLCAD*
                               MODULI OF ELASTICITY
                .10516125E+08     .10405002E+08     .40020924E+07     .30000000E+00
               0.                0.                0.                0.
                .29819612E+08     .21539483E+07     .39796301E+06     .21001350E+00
                .29819612E+08     .21539483E+07     .39796301E+06     .21001350E+00
                .34103981E+08    0.                0.                0.
                                STRESS RESULTANTS
        REDUCE  .59216692E+04    -.86572076E+02    0.

    *** UNLOADING LEADS TO FAILURE OF LAMINATE ***               PROGRAM TERMINATED

***********        W1CHKBT  //// END OF LIST ////
***********        W1CHKBT  //// END OF LIST ////
```

REFERENCES

1. R. S. Sandhu, "Ultimate Strength Analysis of Symmetric Laminates" AFFDL-TR-73-137, February 1974, AF Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, AD 779927.

2. R. S. Sandhu, "Nonlinear Behavior of Unidirectional and Angle Ply Laminates", (Accepted for Publication in the Journal of Aircraft, AIAA, February 1976).

☆ U. S. GOVERNMENT PRINTING OFFICE: 1976 — 657-630/568